THE COMBINED EFFECTS OF RATION SIZE AND FEEDING FREQUENCY ON GROWTH IN POSTLARVAE, JUVENILE AND ADULT *PENAEUS INDICUS* H. MILNE EDWARDS

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DEDICATED TO MY PARENTS

CERTIFICATE

This is to certify that this Dissertation is a bonafide record of work carried out by Kum. Rekha. J. Nair and that no part thereof has been presented before for any other degree.

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PREFACE

World demand for fish is expected to increase to 130 million tonnes as against the present production of about 100 million tonnes by the year 2000 A.D. The increasing fishing pressure has led to over exploitation and stagnation in fish catch. To overcome these problems, aquaculture is one of the several avenues currently being considered in our country as a viable means of diversification of fishery activity. Aquaculture is expected to close the increasing gap between the world demand for fish and their production through capture fisheries. These expectations are based on the fact that aquaculture yields much more fish per unit area than natural waters.

High demand for shrimp in the world market, especially in the industrialized countries, and inability of natural resources to meet the demand have created an almost worldwide interest in shrimp culture during the last two decades. Besides being a good source of animal protein to the teeming millions, fishery products, mainly shrimps contribute a lion's share to India's export earnings. Out of India's total marine export earnings of 1767.43 crores, frozen shrimps alone contributed to about 1180.26 crores (MPEDA,1993)

A decisive factor in successful scientific shrimp farming and achievement of high production levels is the preparation and use of high protein complete feeds. When the cultivated stock is wholly dependent on the feed provided from external sources, the entire nutritional requirement of the organisms for various functions have to be met from the artificial feed. Great impetus has been given to the feed industry for the development of high quality complete feeds and many feed industries have been set up in the recent years.

According to New (1976), feed is normally the largest single item in the running expenditure of a shrimp farm. It has been seen from earlier reports that proper management of feed not only improves pond water quality and shrimp production, but also profitability. Not much work has been done regarding feeding levels of postlarva and juveniles,they being important stages in the culture activities. Available information suggests that among the 15 species of shrimps occurring in the Indian waters, which are suitable for aquaculture, the Indian white prawn Penaeus indicus is identified as one of the most important commercial species. Considering the increased importance of this species for culture activities, three different stages of Penaeus indicus viz. postlarvae, juveniles and adults was selected for the present study.

The objectives of the present investigation are as follows:

i) a complete biochemical and physical evaluation of the three commercial feeds (starter, grower and finisher) used for feeding the different stages of prawns viz. postlarvae, juveniles and adults respectively.

ii) to study the correlation, if any, between varying ration sizes and growth, at the postlarval, juvenile and adult stages.

iii) to evaluate the effect of different feeding frequencies on growth, food conversion ratio, protein efficiency ratio, gross conversion efficiency, net conversion efficiency and survival at the three different stages in the experimental animals.

iv) to record the effect of the varying ration sizes on the enzyme activities of trypsin in the experimental animals.

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INTRODUCTION

Shrimp is called the "Pinkish Gold" of the sea because of its universal appeal, unique taste, high unit value and ever increasing demand in the world market (Sakthivel, 1987). According to reports, export of shrimps ending for the year 1992-93 would be of the order of Rs.1700 crores. It is anticipated that these exports will go up to a still higher level by the end of Eighth Five Year Plan. Shrimp farming is therefore found to be one of the most profitable enterprises of the day with a net return of more than Rs. 1.5 lakhs per hectare per year. Due to its capacity to earn high foreign exchange for the nation, the Ministry of Commerce, Government of India has identified shrimp farming for "extreme focus" and proposes to develop it in all the coastal states on a war footing.

Shrimp farming on a commercial basis requires adequate quantity of hatchery seeds, highly nutritional feed, technology of water quality management and dedicated personnel. Feed plays a vital role in increasing productivity in aquaculture and includes hatchery feed, nursery feed and grow out feed. The feed given should be a complete one, with all the nutrients required by the shrimp. Due to its increasing importance in modern shrimp farming, development of feed is given great importance and a lot of research work is being done on these lines.

Feed constitutes nearly 50% to 70% of the total operating cost in a shrimp farm. As feed quality and cost are directly related, an improvement in quality will inevitably increase feed cost. Hence development of economically viable and biologically efficient diets for commercial species of shrimps in semi-intensive and intensive culture systems is highly warranted to obtain high growth rates and maximum production.

With the rapid progress of semi-intensive and intensive systems of culture, formulation and development of practical feeds meeting the nutritional requirements of candidate species for obtaining optimum growth and survival during the different phases of its growth have been evolved. Accordingly, during the past two decades, there has been considerable advancement in the various aspects of feed technology and several types of compounded feeds have been developed and are being used for the culture of shrimps in different countries of the world.

The best shrimp feed in the world will give poor results, if it is not used properly. Feed management is the most critical factor in determining the profitability of a shrimp farm. Overfeeding causes wastage of feed, water pollution and in turn increased operating cost. Underfeeding on the other hand results in loss of production.

Shrimp are nocturnal, continuous, intermittent feeders, their feeding behaviour dictates the feed management strategy. For proper feed management, importance should be given to both ration size and to frequency of feeding. Although the types of food supplied to semi-cultured shrimps has reached from natural marine food such as trash fish, clams, squid, and marine algae to agricultural products such as yellow corn meal and wheat bran, one of the most promising forms of food for increasing growth and survival of penaeids is a pelleted formula diet. Preliminary results for using formula diets for shrimp mariculture (Kanazawa et al., 1970; Kanazawa et al., 1971; Sick et al., 1972) have revealed that significant growth and survival can be achieved using such diets.

RATION SIZE

Ration is considered to be a driving force and any restriction to it results in a lower metabolic rate.(Brett, 1979; Jose and Jose, 1993). A precise knowledge of the relationship between food requirement and body weight for a particular species and diet would be essential to avoid both overfeeding and restricted growth through submaximum rations. In order to achieve an efficient feeding regime in an aquaculture situation, continual adjustment of the ration level is necessary to compensate the changing requirements. (Sedgwick, 1979). An optimum ration size is very significant when considering the reduction in the cost of operation and also in the environmental hygiene. Ration size should therefore be regulated according to the consumption and diet left over. The quantity of feed offered to shrimps is generally based on its body weight.

Relevant data on the feeding requirements of crustacea are limited and probably reflect more on the variations in behaviour to that expected in the natural environment. Feeding rates for shrimp have been reported to range from 3% to 20% (wet weight) of total biomass of animals per day. (Broom , 1969; Kanazawa et al., 1979; Subramanyam and Oppenheimer , 1969).

Taechanuruk and Stickney (1982) working with fresh water shrimp Macrobrachium rosenbergii showed that feeding rate did not affect protein digestibility of shrimp. Sick et al., (1973) however, reported a decrease in ingestion rate after long exposure to the same pelleted food in their studies on the duration of feeding, amount of food, light intensity and animal size in juvenile Penaeus setiferus.

Studies on the growth and yield of pink shrimp, Penaeus duorarum duorarum showed that growth increased with increased feeding rate(Caillouet et al., 1976). In the same study, different shrimp foods were also tested and it was emphasized that feeding rates were usually dependent upon the number and size of shrimp being fed.

Sreekumaran Nair et al., (1983) studied the growth of Penaeus indicus under different levels of feeding using live earthworm as food and reported that quantity of food along with quality played a decisive role in penaeid prawns.

Relevant data on ration size for postlarva are limited. Manik et al., (1980) conducted laboratory feeding experiments on postlarvae of Penaeus monodon using a formulated feed to obtain baseline information on growth and survival rate of the postlarvae. It was seen in the study that even when the feed was given at 150 percent body weight per day, deterioration of the culture medium was within the tolerable range of the larvae. An inverse relationship between feeding rate and survival was found during a study on the effect of excess feed on postlarvae of Penaeus monodon. Feed was given to the postlarvae at four different concentrations of 10,50,100 and 250 mg $litre^{-1}$. Survivals at day five were 26%, 22%, 10% and 2% respectively. No postlarva survived past day one at a feeding level of 500 mg $litre^{-1}$. (Millamena, 1990).

Al Ameeri and Watanabe (1980) studied the influence of different feed levels on growth rate of the shrimp Penaeus semisulcatus. Shrimps were fed daily with pelleted feeds at different levels and growth rates were noted.

Subrahmanyam and Oppenheimer (1970) worked on the influence of feed levels on the growth of grooved penaeid shrimp Penaeus aztecus and Penaeus duorarum. Shrimps were fed with pellets at 5% and 10% of their body weight and the influence of these levels on growth of three different size groups was tested. Some interesting results noted were that the overall percentage increase in weight gain was higher at 5% feed level compared to 10% level. Smaller animals of 31-40mm showed a higher increment at the lower feed level than at the higher level. It was also seen that smallest and largest size groups showed a negative gain at the higher feed level. This study also showed higher quantities of feed to affect the survival of small and large shrimp.

Similar studies were carried out on juvenile Penaeus merguiensis. (Sedgwick, 1979). Juveniles fed four times daily, increased in weight more rapidly and utilized their food more efficiently than when fed once per day. Maximum ration for prawns given a commercial dry pellet was approximately 12.0% of the wet body weight per day and changed very little as the prawns grew from 0.5g to 1.3g in indoor culture. Food conversion efficiency declined with increasing weight and ration size but the relative loss in efficiency was least when rations were maintained near to the maximum.

The relationship between feeding rate and growth holds good for both prawns as for fishes, as shown by the decreasing relative food consumption of several penaeid prawns in pond culture and intensive experimental systems (Penaeus japonicus, Furukawa, 1972; Penaeus aztecus, Venkataramaiah et al., 1974; Penaeus setiferus, Sick et al., 1973).

Brett and Shelbourne (1975) working on young Sockeye Salmon Oncorhynchus nerka showed a restricted ration to result in a slight increase in growth rate until size became a limiting factor reducing food demand below the prescribed level and thereby reducing growth rate. The specific growth rate and food requirements expressed as a percentage of the body weight fed per day also declined as the mean weight of fish increased. Daily rate at which fish are fed may affect performance of fish as well as utilization of dietary nutrients (Andrews and Page, 1975; Murai and Andrews, 1976).

Bromley (1980) working on turbot, Scophthalmus maximus L showed that the overriding factor governing growth was the rate of food intake. A relationship was worked out between feeding rate, lipid, and protein content of the fish and a very fast growth was accompanied by a marked increase in the condition factor and an elevated lipid content of the fish at the highest feeding rate.

Elliott (1975) working with brown trout Salmo trutta L fed on reduced rations reported that growth rate was affected by many factors including size and metabolic requirements, water temperature and above all the amount of food eaten by the fish. A mathematical model was developed to estimate the daily ration required for different levels of growth ranging from zero to maximum growth. A similar relationship between growth rate and daily rations has been worked out in plaice, Pleuronectes platessa (Rafail, 1968).

Optimum ration size for young Oreochromis niloticus were worked out by De Silva et al., (1986). Specific growth rate was reported to be higher at the higher ration level.

Studies were conducted on early feeding fry of Atlantic Salmon, Salmo salar in an ozonated water reuse system at 17-18°C to determine the optimal feeding level in percent body weight (Poston and Williams, 1991) and they reported that feeding rates as high as 6.43 and 5.46 did not significantly change percentage fat, protein or ash of the fish. Low body fat of fish fed 5.44 and 4.67 percent body weight per day or lower indicated that fish were underfed, , but feeding levels of 6.43 and 5.46 were sufficient.

FEEDING FREQUENCY

The frequency with which animals consume feeds has also been shown to have substantial effect on metabolism (Cohn and Joseph, 1959; Cohn et al., 1963; Stevenson et al., 1964; Leveille and Hanson, 1965, a, b, 1966; Kekwick and Pawan, 1966; Fabry, 1967). In intensive farming operations, feeding frequency has an important role in improving overall yield and reducing the cost of production.

There is a dearth of literature as regards the feeding frequency of Penaeus indicus which along with Penaeus monodon are the commercially important species on the Indian context. Information regarding the feeding frequencies in shrimp nutrition is based upon the recommendation of the commercial shrimp manufacturers and pertains mainly to Penaeus monodon (Table 1).

Heinen and Mensi (1991) worked with freshwater prawns Macrobrachium rosenbergii to find out the best feeding frequency for postlarva. Four feeding schedules were tried and results evaluated. Prawns in the once daily treatments exhibited the best survival, final weight, yield and food conversion ratio. Contrasting results were obtained as a result of

TABLE 1

FEEDING RATES AND FREQUENCIES AS RECOMMENDED BY SHRIMP FEED MANUFACTURERS

COMPANY	SPECIES	(a) DAILY RATION AS % OF BIOMASS PER DAY (b) FEEDING FREQUENCY (PER DAY) (c) ANIMAL SIZE					
GOLD COIN SINGAPORE PTE. LTD.	<u>PENAEUS MONODON</u>	a) b) c)	40-20 5 pl15.35	20-10 5-4 pl35-5g	10-6 4-3 5-10g	6-4 4-3 10-20g	4-25 4-3 20g+
PT MALABAR FEED	<u>PENAEUS MONODON</u>	a) b)	25-15 pl0.01-0.5g	15-10 0.5-3.5g	10-7 3.5-10.5g	7-4 10.5-19.5g	4-3 19.5g
- (LOVELL, 1989)	NOT STATED (N.S.)	a) b) c)	30-20 6 pl15-30	20-8 4-3 pl30-5g	8-6 3 5-10g	6-4 3-2 10-20g	4-3 3-2 20g+
- (CHIU-1988)	<u>PENAEUS MONODON</u>	a) b) c)	N.S. N.S. N.S.	12-4 5 0.5-7g	4-3 5 7-14g	4-3 5 14-22g	4-2 5 22g+
THE HANAQUA GROUP	<u>PENAEUS MONODON</u>	a) b)	25-20 Upto pl 30	20-8 pl30-5g	806 5-10g	6-4 10-25g	5-3 25g+
CP GROUP (CHAROEN POKPHAND)	<u>PENAEUS MONODON</u>	a) b) c)	40-20 3 0.02-0.2g	15-7 3-4 0.2-5g	7-6 3-4 5-12g	6-4 3-4 12-20g	4-2 3-4(4-5) 20g+ Frequency at 20g+ depends on pellet size
NICOLINI HERMANOS S.A.	NOT STATED	a) b)	N.S. N.S.	25-6 1-6g	6.305 6-10g	3.5-2 10-22g	1.8 22g+
AQUASTAR (TROUW INTERNATIONAL S.E. ASIA)	<u>PENAEUS MONODON</u>	a) c)	0.5- 1.0kg/ha pl15-30	0.15-0.8kg per 10,000 0.5-3g	1.2-2.3kg per 10,000 4-8g	2.8-6.5kg/ 10,000 8.20g	6.5-0.01g/ 10,000 20g+

Source: Technical and Economic Aspects of Shrimp Farming - Michael.B.New, Henri de Saram and Tarlochan Singh (Eds) June 1990) the studies on prawn larvae of Penaeus japonicus reared with micro-particulate diets. The prawn larvae had higher survival rates when fed diets at higher feeding concentrations. (0.16 mg diet/larva/day compared to lower concentrations of 0.08 mg diet/larva/day. Survival was higher for larvae fed twice a day rather than once a day. (Teshima and Kanazawa, 1983).

Effect of different feeding frequencies on the length-weight relation of prawns was studied by Sreekumaran Nair et al., (1982, 1983). Prawns were fed on live earthworm and the four different frequencies followed were two, three, four and five times daily. The different frequencies did not exert any influence on the length-weight relation. The different feeding levels showed definite effect on the growth rate, the maximum growth being shown by prawn fed five times a day. Fortnightly growth increments during the experimental period varied between 0.92 and 8.5mm depending on the four different feeding frequencies viz. two, three, four and five times daily. The growth pattern shown by M. dobsoni were similar to that published for Penaeus indicus (Sreekumaran Nair et al., 1987).

Liao and Lee (1972) using an unspecified penaeid, recorded improved growth if daily feeding was interrupted by occasional 'starved' days. The frequency of starved days which gave optimum growth tended to increase with the mean size of the prawns.

Frequency studies conducted with fish also reflect a degree of inconsistency. Kono and Nose (1971) established a relationship between stomach size and optimum feeding frequency for a number of different species. Feeding studies conducted with channel catfish fry showed that feed intake rate decreased as fish grew in weight. Smaller fish required more freouent meals than larger or older equivalents. (Murai and Andrews, 1976).

Working on the effects of feeding frequency on culture of catfish, it was shown that weight gain and food efficiency were less in fish fed greater number of times per day (Andrews and Page, 1975). De Silva et al., (1986) working on feeding frequency in young Oreochromis niloticus reported that optimum feeding frequency differs between size groups. Studies on the effect of feeding frequency on growth and consumption in the siluroid catfish, Heteropneustes fossilis (Bloch) has showed an increase in feeding frequency associated with increase in consumption, but a simultaneous decrease in the gross conversion efficiency (Singh and Srivastava, 1984)

ENZYME STUDY

Nutritional studies conducted with shrimp have classically been confined to emperically designed dietary trials, while investigations of the bioenergetics and digestive physiology of the organisms have received less emphasis. Numerous investigations (New, 1976, 1980; Biddle, 1977) have examined the effects of diet on the growth rate of the shrimp. However, one can question the use of growth alone as a measure of the nutritional suitability of a diet since many other environmental factors can influence growth (Wickins, 1976).

Until recently most investigations concerning the digestive enzymes of shrimp have been qualitative and focussed on the comparative aspects of digestion. Since shrimp are now being evaluated for commercial culture, the changes in enzyme activities during the life cycle and adaptation to new diets are being examined quantitatively. Therefore, another objective of this research was also to obtain information concerning the changes that occur in the activity of the proteolytic enzyme trypsin in the postlarval, juvenile and adult shrimp *Penaeus indicus* in response to ration size and frequency. In addition, the data were compared with other nutritional information, growth, survival rate and the feed conversion which were obtained from the feeding trials in the same population of shrimp (Smith *et al.*, 1984) This new information could be employed for evaluation of diets in shrimp.

The aforementioned research works show that there may be some relationship between ration size and feeding frequency in all the three stages of prawns viz, postlarva, juveniles and adults. Though some data is available regarding feeding frequencies and ration size, data specific for the three stages of the Indian white prawn, *Penaeus indicus* are few and hence a study on these lines was considered highly essential.

Among the 15 species of prawns available in Indian waters suitable for aquaculture, the Indian white prawn *Penaeus indicus* is identified as one of the most important commercial species. Therefore, in this study an attempt has been made to study the combined effects of both ration size and feeding frequency on the growth of different stages of the Indian white prawn *Penaeus indicus* using a pelleted feed.

MATERIALS AND METHODS

Experiments were conducted in the laboratory to study the effects of varying ration size and feeding frequencies on growth in different stages of the Indian white prawn Penaeus indicus. The three different stages chosen were postlarvae, juveniles and adults. Data on growth in terms of length and weight, survival, feed conversion ration (FCR), specific growth rate (SGR), protein efficiency ratio (PER) and body composition viz. moisture, protein, lipid and ash of the experimental animals were obtained from these experiments. Controls maintained on fresh clam meat were also run for each stage. The feed used for the experiment was a commercial shrimp feed procured from a company of international repute. Three different feeds viz. starter, grower and finisher were used for the postlarvae, juvenile and adult stages of prawns respectively. Analysis of the feeds was carried out to ascertain their proximate composition. Analysis was done before the start of the animal experiments. The control groups were fed ad libitum with the meat of Sunetta scripta.

I. BIOCHEMICAL ANALYSIS

Biochemical investigations were performed on the feed samples and experimental animals by the following procedures:

Moisture content: Moisture content in the feed samples and prawns was determined gravimetrically by oven drying the samples at 80°C for feed samples and at 60°C for prawns, till concurrent dry weights were obtained. Percentage of moisture in the samples were calculated as follows:

$$\text{Moisture (\%)} = \frac{\text{Weight of fresh sample} - \text{weight of dry sample}}{\text{Weight of fresh sample}} \times 100$$

Ash content

Weighed dried samples of the feed and prawn were taken in silica

Plate I - Feed used for postlarvae of *P. indicus*.

Plate II - Feed used for juveniles of *P. indicus*.


STARTER


GROWER

Plate III - Feed used for adults of *P. indicus*

Plate IV - Part of the experimental set up.


FINISHER

crucibles, separately, and ashed in a muffle furnace at 600°C for 6 hours. Percentage ash was calculated as follows:

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

Crude Protein

Total nitrogen in feed samples and experimental animals was determined by the "Kjeldahl method" and the result obtained multiplied by the conversion factor of 6.25 to give crude protein (AOAC, 1975).

Crude Fat

Lipid content was determined using soxhlet extraction method (AOAC, 1970) using petroleum ether (b.p 60-80°C) as solvent.

Crude Fibre

Crude fibre of feed samples was determined as the fraction remaining after digestion with standard solutions of sulphuric acid (0.23N) and sodium hydroxide (0.31N) under carefully controlled conditions.

Chitin

Chitin in the feeds was determined by the method of Richards (1978). The sample was first digested with sodium hydroxide (2N) followed by hydrochloric acid (2N). The residue obtained was treated as for normal protein digestion and value calculated from nitrogen by multiplication with the factor 14.51.

CALCIUM: Calcium was determined using the residue from ash determination by titration method (New M.B. 1987) and calculated as follows:

Fig. 1. Standard curve for Phosphorous.

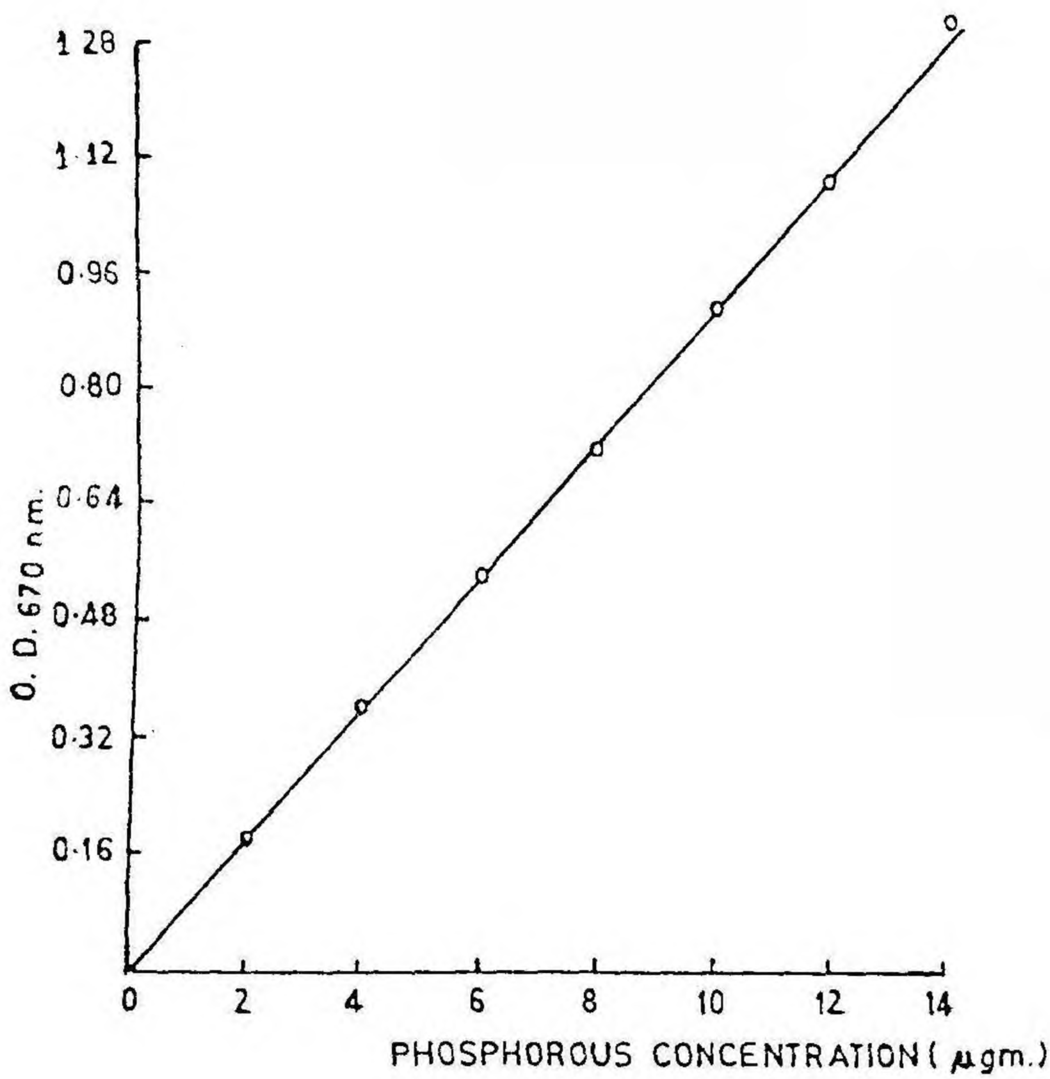

1.28
1.12
0.96
0.80
0.64
0.48
0.32
0.16
O. D. 670 nm.
0
2
4
6
8
10
12
14
PHOSPHOROUS CONCENTRATION (µgm.)

Fig. 1

$$\text{Calcium (\%)} = \frac{\text{ml permanganate solution}}{\text{Weight of sample}} \times \frac{\text{aliquot used (ml)}}{250} \times 0.1$$

SODIUM: Sodium present in the feed was determined using fresh sample. (New, M.B. 1987) and result calculated as Sodium Chloride

$$\%NaCl = \frac{(15 - \text{ml } 0.1\ N\ \ NH_4CNS \times 0.585)}{\text{Weight of sample}}$$

PHOSPHOROUS: Phosphorous present in the feed was analysed by Molybdovanadate method (New M.B. 1987) and determined from a standard curve (Fig.1).

Physical evaluation of feeds: The physical appearance of the feeds viz. colour, shape, size and pellet diameter were recorded.

The water stability of the feeds was determined over a period of 5 hours by employing the method described by Jayaram and Shetty (1981) with minor modifications. Five grams of each feed were taken in a 4" x 4" No. 30 bolting silk cloth and after stapling the edges to form a pouch were immersed separately in plastic troughs containing 10 1 of 32 ppt seawater provided with aeration. At set intervals of 1,3 and 5 hours respectively, 3 pouches for each feed were removed from the trough and after rinsing with distilled water to remove adhering salts, the excess water was drained and the residue dried in a hot air oven at 105°C for 30 minutes, followed by further drying at 65°C to a constant weight, and cooled in a dessicator. The mean difference in weights of pouches containing the feeds before immersion and after drying were used to calculate the percentage dry matter loss, which is a measure of the water stability of the pellets for the corresponding time intervals.

II. EXPERIMENTAL SET UP

Experiments were carried out using plastic tubs of 5 l, 15 l and 25 l capacity respectively for the different stages. The tubs were arranged on vertical racks. Each tub was provided with aerator stones so that aeration was maintained uniformly throughout the experimental period. The tubs were covered with nylon screen to prevent the escape of animals.

Seawater for experimental purposes was collected from the open sea off Cochin. It was transported to the laboratory in plastic jerry cans, filtered using bolting silk (No. 30) and pooled into 100 l fibreglass tanks. The salinity of the water used throughout the experimental period was maintained at 30% for postlarvae, while for juveniles and adults it was adjusted to $\underline{20} \pm 2\%$ by diluting with tap water (Table 2) since juvenile P. indicus prefer lower salinities (Colvin, 1976; Paul Raj 1976; Paul Raj and Sanjeeva Raj, 1980).

Experimental analysis:

POSTLARVA:

Postlarvae of Penaeus indicus belonging to the same broodstock were obtained from the Prawn Culture Laboratory of Central Institute of Brackishwater Aquaculture, Narakkal, Cochin. These were transported in polythene bags by means of oxygen packing to the laboratory in the shortest possible time. They had an average initial length of 2.98 ± 0.21cm and an average initial weight of 0.1313 ± 0.01 gram. The postlarvae were introduced to 2½ x 1½ x 1 ft perspex tanks and acclimatized to the laboratory conditions for a week before start of the experiment.

JUVENILES:

Juveniles of Penaeus indicus having an average initial length of 6.353 ± 0.39 cm and average initial weight of 1.49 ± 0.28 g were used for the experiment. These were collected from backwater canals near Pallithode, Alleppey District. These were transported in plastic bins containing water from the same locality to the laboratory in the shortest possible time.

ADULTS:

Adults of Penaeus indicus were collected from extensive culture ponds at Pallithode, Alleppey District using cast net. They had an average initial length of 9.34 ± 1.30cm and average initial weight of 4.40 ± 1.13g. They were transported to the laboratory using plastic bins containing water from the same locality within the shortest possible time. During the transit phase, animals were not fed.

Juvenile and adult prawns were also acclimatized to laboratory conditions for a week, after which the animals were visually selected, and randomly distributed into the experimental tubs. The number of animals maintained was 14 per tub for postlarvae, 7 per tub for juveniles and 7 per tub for adults and two replicates were maintained for each

TABLE 2

HYDROGRAPHIC PARAMETERS MAINTAINED DURING THE EXPERIMENT.

Treatment	Salinity (ppt)	Oxygen(ml/l)	pH	Temperature (°C)
Postlarva	30 ± 1	4 ± 0.3	8.02 ± 0.2	28.5 ± 0.5
Juveniles	20 ± 2	4 ± 0.2	8.05 ± 0.1	28.0 ± 0.5
Adults	20 ± 2	4 ± 0.3	8.00 ± 0.1	28.4 ± 0.2

TABLE 3

THE FEEDING FREQUENCIES ADOPTED IN THE PRESENT INVESTIGATION

Frequency	Timing
One time-morning	8.00 hr.
One time-night	20.00 hr.
Two times	8.00 hr. and 20.00 hr.
Three times	8.00 hr; 14.00 hr; 20.00 hr.
Four times	8.00 hr, 12.00 hr, 16.00 hr, 20.00 hr.

treatment. Prior to the start of the experiment, the length and weight of the animals was again recorded. The total length of the animal was measured from tip of the rostrum to the tip of the telson. For this purpose the animals were blotted dry carefully between the folds of filter paper, weighed on a Mettler electronic balance to the nearest mg, and were immediately transferred to the experimental tubs. Feeding was suspended and animals starved for 48 hours before the start of the experiment.

About 20 animals from each stage were measured, weighed and left for drying in the oven at 80°C for 48 hours at the start of the experiment. These dried prawns were used for analysis of their body composition.

Ration size and feeding frequency

Four different ration sizes were selected for each stage and these were based on earlier published works. (New M.B. 1989; Sick et al., 1973). The four different ration sizes (expressed as % body weight) chosen for postlarvae were 2%, 12%, 22% and 32%. The four different ration sizes chosen for juveniles were 2%, 8%, 12% and 16%, whereas for adults it was 1%, 4%, 6% and 8%. Four different feeding frequencies were selected to know the effect of different feeding frequencies on growth. The different feeding frequencies adhered to are specified in Table 3. One time night feeding at 20.00 hours was carried out for postlarvae in addition to one time morning feeding at 8.00 hours to know the variation in growth with respect to time. The timings were adjusted so as to provide uniform time interval between the different feeding frequencies.

The feed was provided to the animals in preweighed glass petridishes.

Feed for Control Group

The control group was fed *ad libitum* with fresh clam meat. Meat of white clam *Sunetta scripta* was collected fresh from Murukkumpadam. The shell and waste was removed, the weighed quantity of meat cut into fine pieces and fed to the control group. This group was specifically maintained to take care of the supply of nutrients obtained in natural food chains which may be deficient in a commercial feed.

Collection of Faecal matter and left over food

Left over food in the experimental tubs was collected from the petridishes after siphoning out any contaminating faecal matter. Each petridish was washed with distilled water to remove the adhering salts and transferred to an oven for drying at 80°C for 24 hours. The faecal matter was removed by slow siphoning of the water through a narrow plastic tube and collected at the other end on a bolting silk. This was also washed with distilled water, and oven dried at 80°C for 24 hours. The dried faecal matter was collected in preweighed conical flasks and stored in a dessicator.

Water exchange:

Daily one-fourth of the water in the tubs was siphoned out and replenished with an equal amount of fresh sea water. Complete water replacement was done once a week.

Every 10 days of the experiment, the animals were randomly selected from the tubs and their lengths and weights measured as before. The experiment was terminated on the 30th day and after the final lengths and weights had been recorded, the animals were dried in an oven at 60°C for 48 hours. Dried samples were then powdered using a porcelain mortar and pestle and the biochemical composition estimated.

Physiochemical parameters like temperature, pH, salinity, dissolved oxygen were monitored throughout the experimental duration. Water temperature was measured using an ordinary thermometer of 0-50°C range with 0.1 accuracy. Salinity was estimated by Mohr-Knudsen method and dissolved oxygen using the modified Winkler method, as given by Strickland and Parsons (1968). The pH of water was measured using a digital pH meter. (Table 2).

III. <u>RECORDING OF DATA</u>

<u>Survival rate:</u> Daily the population of prawns was recorded from each of the experimental treatments and the mean number of surviving animals recorded. The final survival rate was calculated using the following formula:

$$\text{Percentage survival} = \frac{\text{Final numbers of prawns}}{\text{Initial number of prawns}} \times 100$$

IV. GROWTH PARAMETERS:

The following were some of the parameters studied for estimating growth of the experimental animals.

Percentage gain in length/weight

$$= \frac{\text{Mean final length/weight - Mean initial length/ weight}}{\text{Mean initial length/weight}} \times 100$$

Food conversion ratio (FCR) $= \dfrac{\text{Food consumed (g)}}{\text{Average live weight gain (g)}}$

Protein efficiency ratio (PER) $= \dfrac{\text{Average live weight gain (g)}}{\text{Total protein consumed (g)}}$

Specific growth rate (SGR) $= \dfrac{\text{Average live weight gain}}{\text{No. of days of the experiment}} \times 100$

Gross conversion efficiency (K_1%) $= \dfrac{\text{Average weight gain}}{\text{Consumption}} \times 100$

Net conversion efficiency (K_2%) $= \dfrac{\text{Average weight gain}}{\text{Assimilation}} \times 100$

V. OPTIMUM RATION SIZE

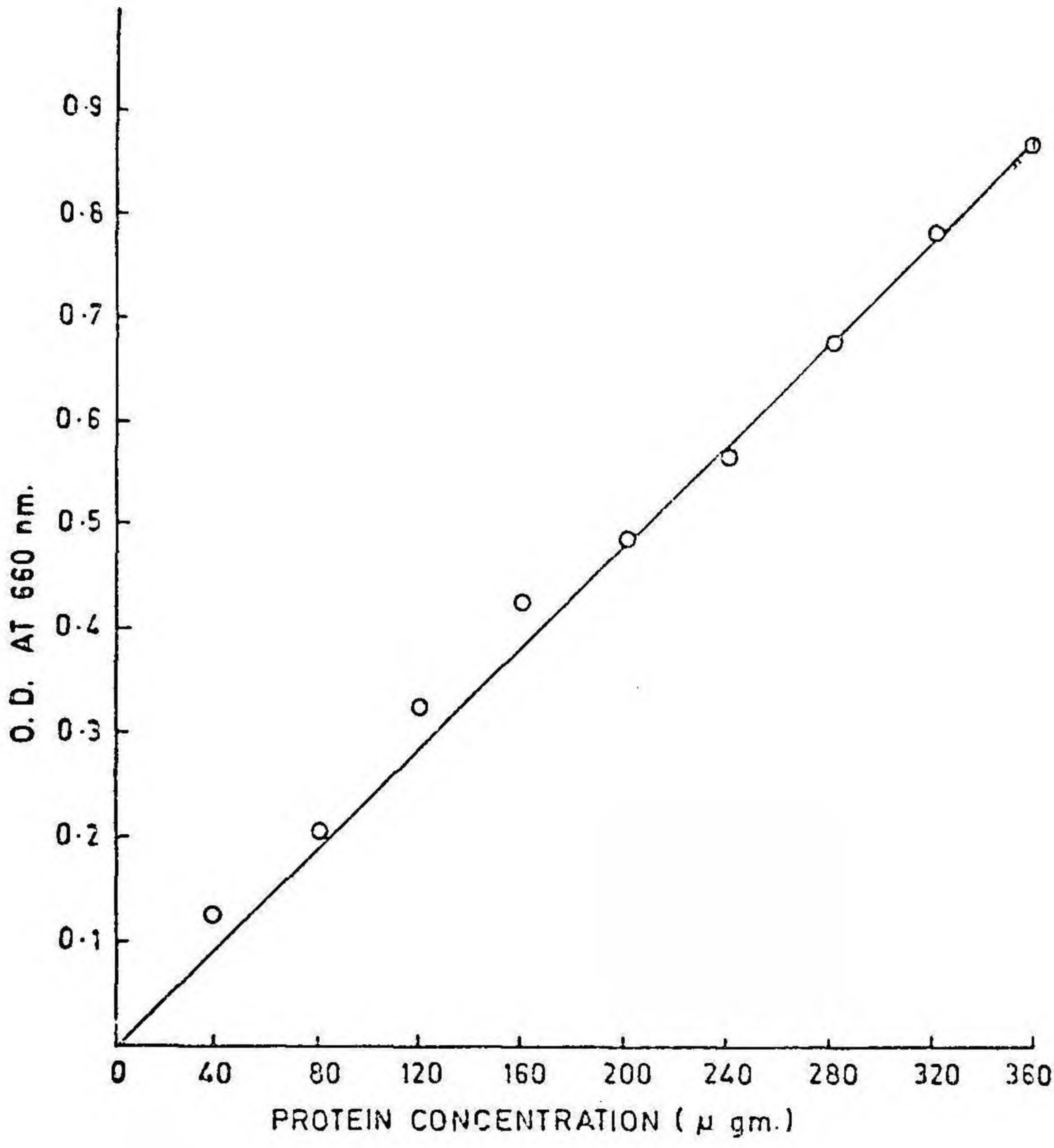
Specific growth rate defined as $G = \dfrac{\log_e W_1 - \log_e W_0}{t_1 - t_0} \times 100\%$ weight d^{-1}

was used as the expression of growth for investigating changes in the response of the prawns to the various ration sizes. G was plotted against ration level for each feeding frequency and by construction of asymptotic curves through the data, ration size was obtained geometrically (Sedgwick, 1979). The point at which the curve flattened gave the ration which stimulated maximum growth - maximum ration. A tangent to the curve from the origin defined the ration which provided for the greatest growth with the least intake, i.e. the most efficient or optimum ration. Extension of the relationship to cut the abscissa also gave the maintenance ration, i.e. that which maintained the animal without weight change. Starved controls were maintained, so that the lower regimes of the curves could be defined and maintenance ration's estimated.

VI. ENZYME ANALYSIS

Upon termination of the growth experiments, the digestive tracts of the shrimp from each treatment were assayed for trypsin. The digestive gland, stomach and midgut of each shrimp was homogenized individually ($n = 6$ for postlarvae and juvenile and $n = 5$ for adults) in 10 ml of 0.05 M Tris buffer, pH 7.8, containing 0.02 M $CaCl_2$ using a high speed tissue homogenizer. The resulting homogenate was centrifuged at 4800 x g at 0.5°C for 60 minutes and the supernatant was used for the assay. The total protein content of the extract was determined according to the method of Lowry et al.,(1951) and protein calculated from a standard curve prepared using Bovine Serum Albumin (Fig 2). Trypsin (Enzyme Commission Number E.C. 3.4.4.4) activity was assayed using the benzoyl - DL - arginine - P - nitroanilide (BAPNA) method of Erlanger et al., (1969). Controls consisted of shrimp from the same initial population which had been starved for 2 weeks, a period during which digestive enzyme

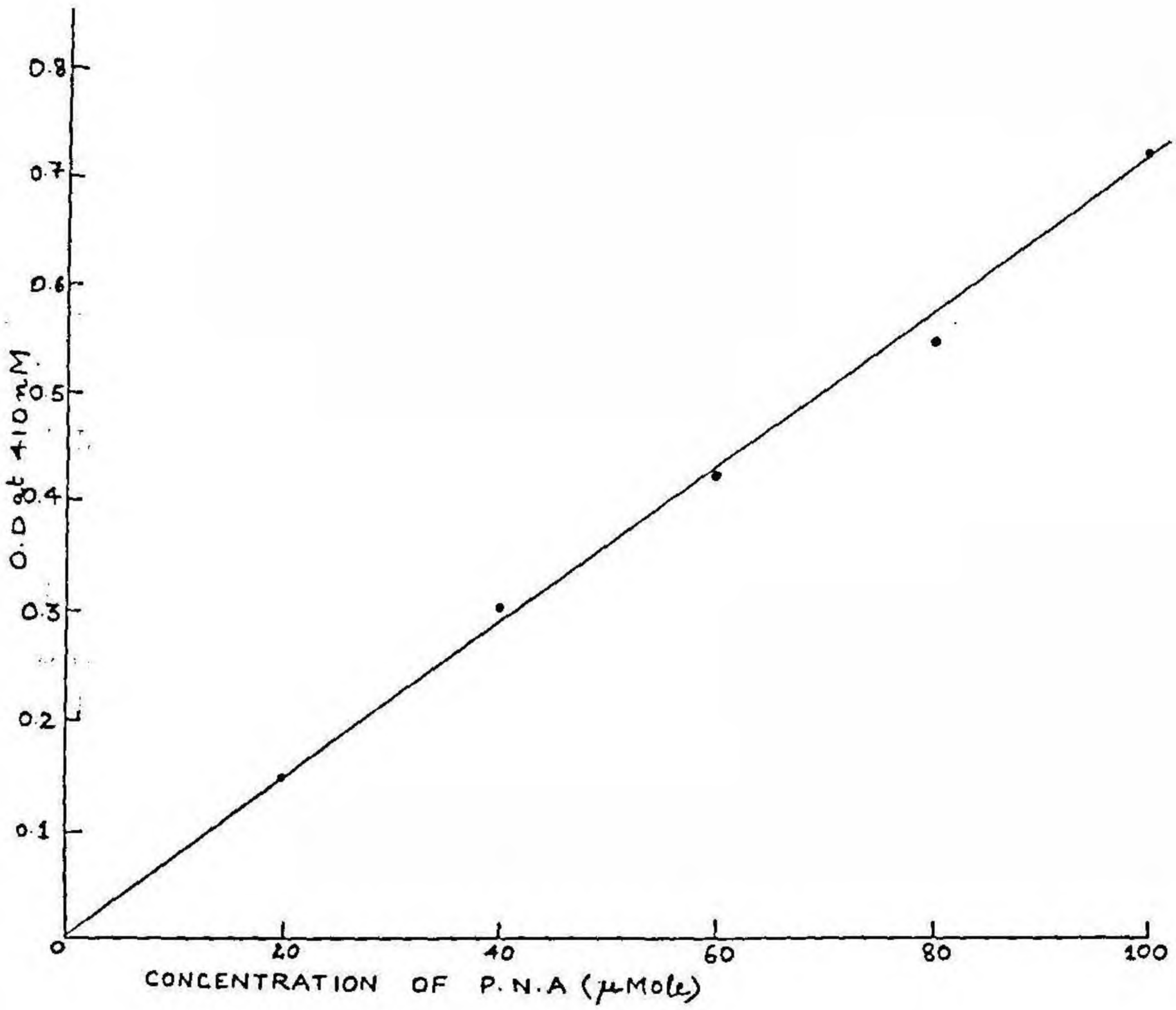
Fig. 2. Standard curve for protein.



O.D. AT 660 nm.
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
40
80
120
160
200
240
280
320
360
PROTEIN CONCENTRATION (μ gm.)

Fig.2

Fig. 3. Standard curve for enzyme activity.



0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
O.D at 410 nM
CONCENTRATION OF P.N.A (μMole)

Fig. 3

activity reaches a baseline value (Cuzon et al., 1980). Enzyme activity was expressed as total activity (amount of product produced per minute per gram of wet tissues) and specific activity (amount of product produced per minute per mg protein). An enzyme unit equals that amount of enzyme which causes an increase in absorbance of 1.0 optical density (O.D.) units/ min. in the reaction mixture (Fig 3). The activity of each enzyme was reported as a population mean ± the S.E. for each experimental treatment

VII. STATISTICAL ANALYSIS

Data obtained in the feeding experiments was subjected to analysis of variance (ANOVA) following the method of Snedecor and Cochran (1971). Differences in treatment means were determined by F test.

RESULTS

Experiments were conducted to evaluate the combined effects of ration size and feeding frequency in postlarvae, juvenile and adult *Penaeus indicus* and the results are as given:

I. ANALYSIS OF THE COMMERCIAL FEED SAMPLES:

Physical characteristics of the feeds

The physical characteristics of the starter, grower and finisher feeds are given in detail in Table 4. A striking characteristic was the uniformity in pellet shape and size maintained by the three feeds. The starter feed was of pale brown colour with the crumbles averaging in size of 1 mm with a diameter of 2mm. The grower feed was brown in colour with the pellets averaging in size of 3 mm with a diameter of 2.2 mm. The finisher feed was dark brown in colour with pellets averaging in size of 8 mm and with a diameter of 2.2mm.

Water stability:

The results of the water stability experiments are given in Fig. 4. The three feeds *viz.* starter, grower and finisher were quite stable in sea water with 90-92% dry matter remaining at the end of one hour. This decreased to 86-89% after two hours. However, at the end of five hours, only a marginal additional loss ranging from 3-4% was recorded in the case of each of the feeds showing them to be highly water stable and designed specifically for penaeid shrimp.

TABLE 4

PHYSICAL CHARACTERISTICS OF THE THREE COMMERCIAL FEEDS.

Feed	Pellet size	Physical appearance
Starter	2.0 x 1.0 mm	Pale brown compact crumbles
Grower	2.2 x 3.0 mm	brown compact pellets
Finisher	2.2 x 8.0 mm	brown compact pellets

BIOCHEMICAL ANALYSIS

Biochemical analysis of the three feed samples was carried out and the results given in Tables 5 and 6.

Moisture content:

The grower feed recorded the lowest moisture content of 7.4%, followed by finisher feed with 8.35% and starter feed with 10.83%.

Crude protein:

The highest crude protein content of 36.09% was obtained in case of the starter feed, while finisher feed recorded the lowest value of 29.53% and grower a value of 34.45%.

Lipid content:

Lipid values were more or less similar for all three feeds with the maximum level of 8.5% in finisher feed, followed closely by a value of 8.0% and 7.5% in the starter and grower feeds respectively.

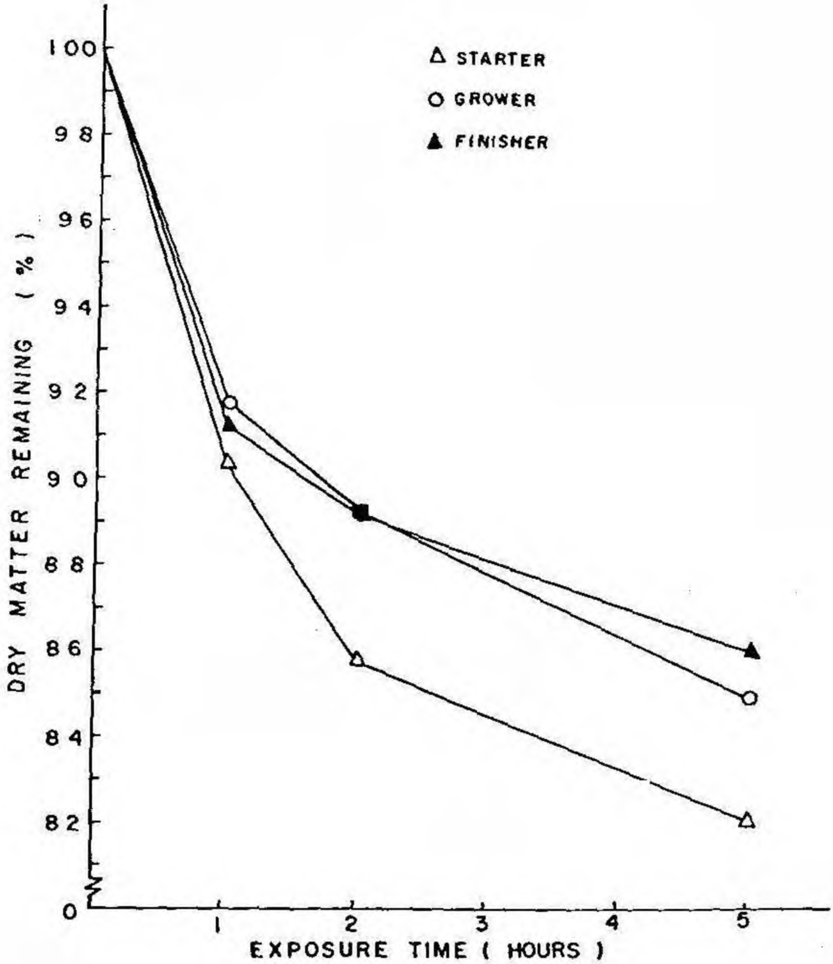
Crude Fibre:

Crude fibre values of the starter and finisher feeds were quite similar being 2.34% and 2.8% respectively. The grower feed recorded a slightly higher value of 3.2%.

Nitrogen free extract (NFE):

The finisher feed had the highest value of 59.17% followed by grower and starter with 54.85% and 53.57% respectively.

Fig. 4. Dry matter weight (%) of the three commercial feeds in water.



STARTER
GROWER
FINISHER
100
98
96
94
92
90
88
86
84
82
0
DRY MATTER REMAINING (%)
1
2
3
4
5
EXPOSURE TIME (HOURS)

Fig. 4

TABLE 5

PERCENTAGE CHEMICAL COMPOSITION OF THE THREE COMMERCIAL FEEDS

Constituent	Starter	Grower	Finisher
Moisture	10.83	7.41	8.35
Dry Matter (DM)	89.17	92.59	91.65
Crude protein*	36.09	34.45	29.53
Ether Extract*	8.00	7.50	8.50
Crude Fibre*	2.34	3.20	2.80
Nitrogen free**	53.57	54.85	59.17
Organic Matter (OM)***	76.55	79.00	80.49
Ash*	12.62	13.59	11.16
Acid Insoluble Ash	9.88	12.69	10.95
Energy value**** (KJ g^{-1})	20.85	20.48	20.47

* Calculated on DM%

** NFE calculated by difference = 100 - (Moisture % + CF% + EE% + CP)

*** OM = dry matter % - Ash %

**** Energy values calculated as protein 23.4 KJ g^{-1}; fat 39.8 KJ g^{-1} and carbohydrate 17.2 KJ g^{-1}; fibre was assumed to have zero energetic value (Cho *et al.*, 1982).

TABLE 6

CHITIN AND MINERAL CONTENT OF THE EXPERIMENTAL FEEDS

COMPOSITION	STARTER(%)	GROWER (%)	FINISHER (%)
CHITIN	1.58	1.32	1.28
MINERALS:-			
SODIUM	0.62	0.52	0.52
CALCIUM	2.95	2.25	2.15
AVAILABLE			
PHOSPHORUS	0.71	0.64	0.55

Ash content:

The grower feed recorded the highest value of 13.59% as the ash content while the finisher feed had the lowest at the 11.16%. Ash content of the starter feed was 12.62%.

Energy value:

Energy values were calculated for the three feeds based on their protein, fat and carbohydrate contents. Starter feed recorded 20.85 kjg^{-1} and finisher an energy value of 20.48 kjg^{-1} respectively.

Chitin:

Starter feed recorded the highest chitin content of 1.58 while chitin values for grower and finisher were 1.32 and 1.28 respectively.

Calcium:

The highest calcium content was recorded for the starter feed at 2.95% with values for grower and finisher being 2.25% and 2.15% respectively.

Sodium

Values for sodium were 0.62% for starter and 0.52% each for grower and finisher respectively.

Available phosphorus:

Available phosphorus content was maximum for starter feed at

0.71% followed by grower and finisher which recorded values of 0.64% and 0.55% respectively.

The biochemical composition of the feeds used were in compliance with the nutritional requirements of shrimp and all the nutrients were within the prescribed limits.

II. ANIMAL EXPERIMENTS

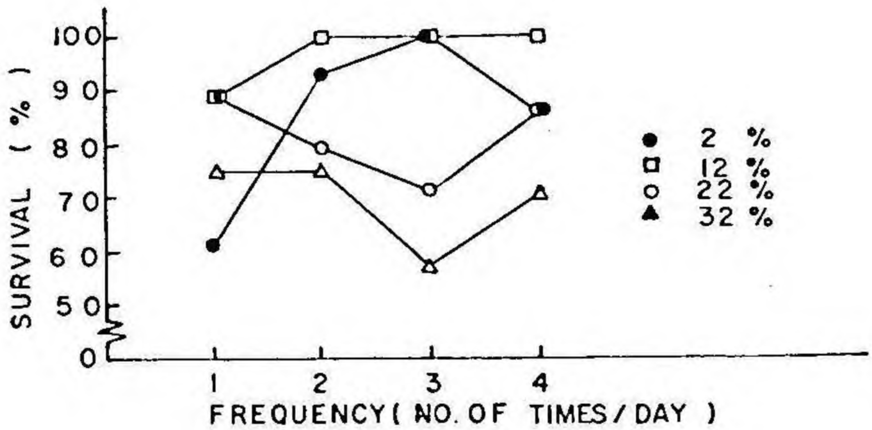
POSTLARVAE

Experiments to evaluate the combined effects of ration size and feeding frequency in postlarvae of Penaeus indicus were carried out, the initial average length and weight for all the groups in this experiment comprising one time morning and night feeding, two times feeding, three times feeding and four times feedings at the four ration sizes viz. 2%, 12%, 22% and 32% being 2.98 cm and 0.131 g respectively. During the 30 day feeding experiments, the postlarvae readily accepted the feeds and survival ranged from 57 to 100 percent (Table 9 to11),(Fig 5)Survival was found to be statistically significant ($P < 0.05$) with regard to change in ration size though frequency of feeding failed to elicit any significant difference ($P > 0.05$) (Table 8). The growth responses under 2% ration size are given in Table 7. The various treatments failed to reflect any significant difference ($P > 0.05$) in the performance in terms of FCR, PER, K_1 % and K_2 % though significant difference was observed in terms of specific growth rate ($P < 0.01$).

Fig. 5. Effect on survival of P. indicus postlarvae with change in

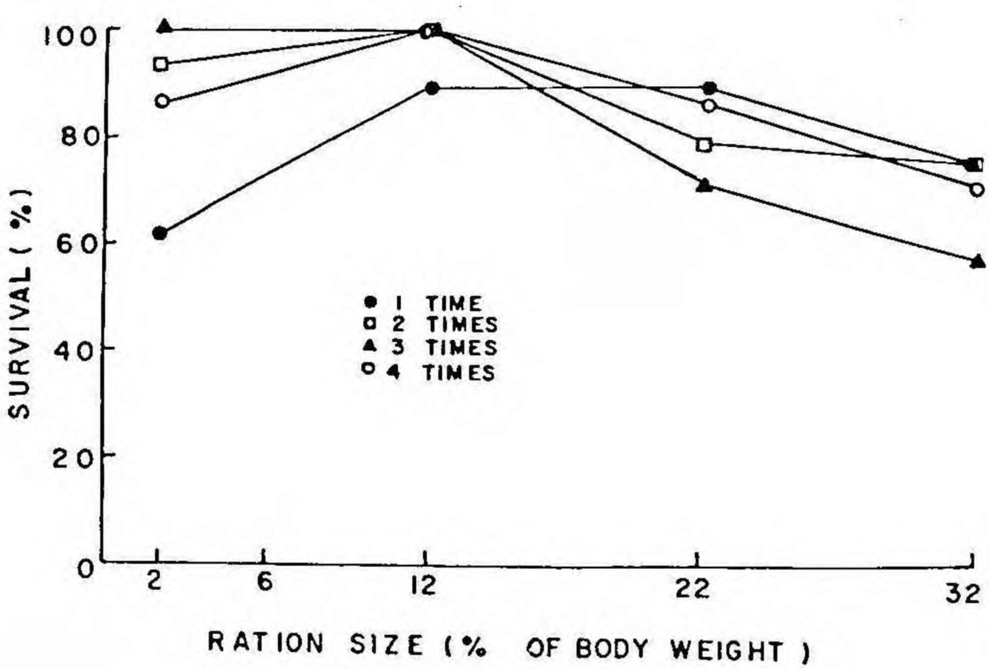
(a) feeding frequency and

(b) ration size



100
90
80
70
60
50
0
SURVIVAL (%)
1
2
3
4
FREQUENCY(NO. OF TIMES / DAY)
2 %
12 %
22 %
32 %

Fig. 5(a)



100
80
60
40
20
0
SURVIVAL (%)
I TIME
2 TIMES
3 TIMES
4 TIMES
2
6
12
22
32
RATION SIZE (% OF BODY WEIGHT)

Fig. 5(b)

TABLE 7

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF *P. INDICUS* POSTLARVAE FED AT TWO PERCENT RATION SIZE

Parameters	Frequency of Feeding				
	One time		Two times	Three times	Four times
	Morning	Night			
% Increase in length	40.42	49.00	22.55	6.14	5.46
% Increase in weight	174.50	185.34	102.84	2.44	5.56
Survival (%)	61.00	93.00	93.00	98.00	86.00
S.G.R.	0.19	0.23	0.11	0.03	0.07
F.C.R.	1.74	1.34	1.83	8.18	4.66
P.E.R.	1.59	2.07	1.52	0.34	0.60
K_1%	57.47	74.63	54.80	12.23	21.46
K_2%	63.93	103.38	87.36	40.00	43.89

SGR - Specific Growth Rate; FCR-Food Conversion Ratio;

PER - Protein Efficiency Ratio; K_1%-Gross Conversion Efficiency

K_2%-Net Conversion Efficiency.

TABLE 8

ANALYSIS OF VARIANCE FOR SURVIVAL OF POSTLARVAE

Source	Degree of Freedom	Sum of Squares	Mean Square	F Value	Remarks
Ration	3	1500.95	500.32	3.92	Sig (5%)
Frequency	4	173.70	43.43	0.34	N.S.
Error	12	1532.30	127.69		
Total	19	3206.95			

TABLE 9

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF *P. INDICUS* POSTLARVAE FED AT TWELVE PERCENT RATION SIZE.

Parameters	Frequency of Feeding				
	One time		Two times	Three times	Four times
	Morning	Night			
% Increase in Length	13.14	28.78	21.57	96.38	78.72
% Increase in weight	61.08	112.49	94.29	477.43	515.46
Survival (%)	89	79	100	100	100
S.G.R.	0.52	0.74	0.56	0.80	1.24
F.C.R.	1.41	6.02	1.49	1.82	1.09
P.E.R.	1.97	0.46	1.86	1.65	2.55
K_1%	70.92	16.61	67.11	54.95	91.74
K_2%	83.57	18.31	78.32	94.65	146.92

SGR - Specific Growth Rate; FCR-Food Conversion Ratio;

PER - Protein Efficiency Ratio; K_1%-Gross Conversion Efficiency

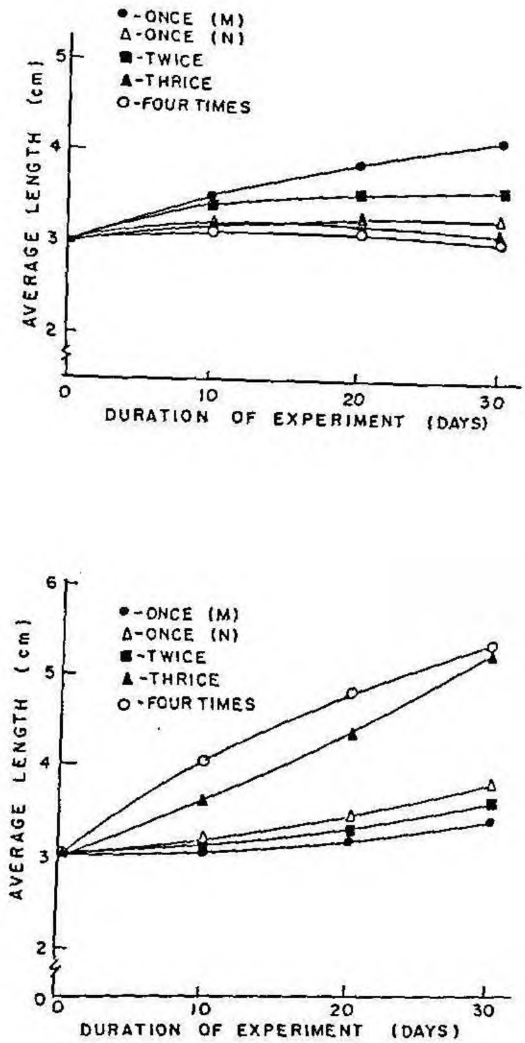
K_2%-Net Conversion Efficency.

Length and weight:

Results on final average increase in length and % increase in length are depicted in Fig. 6 and Table 7. In the two groups maintained at 2% ration size <u>viz.</u> one time morning feeding and two times feeding there was a final average gain in length of 1.2 cm and 0.67 cm respectively which resulted in a concomittant 40.42% and 22.55% increase in length respectively. As regards the % increase in length, of the other 3 groups, <u>i.e.</u> one time night, three times and four times feeding, there was a concomittant percentage increase in length of 49.00, 6.14 and 5.46 respectively. Final average weight gain and % increase in body weight of the postlarvae fed at 2% ration size (Fig. 7 and Table 7) followed a similar trend as that observed in case of length at the different feeding frequencies.

As regards the increase in final average length of postlarvae fed at 12% ration size, at the different frequencies the final average length for all the 5 groups (Fig No. 6 and Table No. 9) ranged from 3.38 cm to 5.33 cm respectively at the end of 30 days feeding, with no significant difference ($P > 0.05$). Percentage increase in length (Table No. 9) however reflected 13% and 22% fold increase in the case of postlarvae fed once in the morning and two times at 12% of their body weight. Percentage increase in length at the other three feeding frequencies was comparatively high. The final average weight gain for postlarvae fed at the five different frequencies at 12% ration size are depicted in Fig.7. Percentage increase in weight (Table No. 9) was comparatively very less in animals fed once in the morning (61) and 2 times (94) compared to those fed once in the night (113), 3 times (477) and 4 times (516).

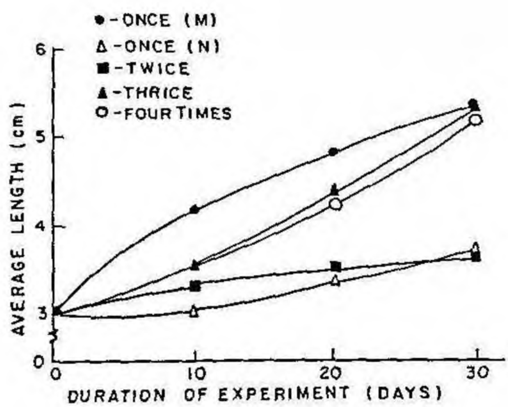
Fig. 6(a). Average increase in length of _P. indicus_ postlarvae fed at the 2% and 12% ration size.



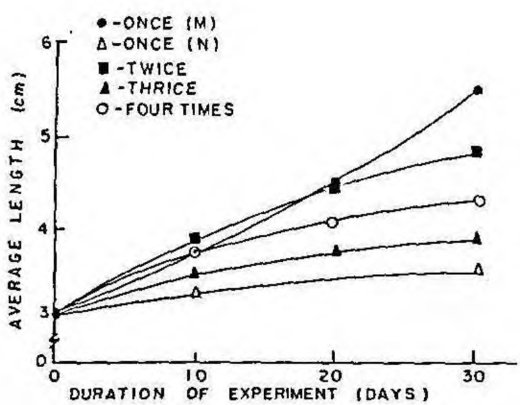
● - ONCE (M)
Δ - ONCE (N)
■ - TWICE
▲ - THRICE
O - FOUR TIMES
AVERAGE LENGTH (cm)
DURATION OF EXPERIMENT (DAYS)
● - ONCE (M)
Δ - ONCE (N)
■ - TWICE
▲ - THRICE
O - FOUR TIMES
AVERAGE LENGTH (cm)
DURATION OF EXPERIMENT (DAYS)

Fig. 6(a)

Fig. 6(b). Average increase in length of P. indicus postlarvae fed at the 22% and 32% ration size.



●-ONCE (M)
Δ-ONCE (N)
■-TWICE
▲-THRICE
O-FOUR TIMES
AVERAGE LENGTH (cm)
6
5
4
3
0
0
10
20
30
DURATION OF EXPERIMENT (DAYS)



●-ONCE (M)
Δ-ONCE (N)
■-TWICE
▲-THRICE
O-FOUR TIMES
AVERAGE LENGTH (cm)
6
5
4
3
0
0
10
20
30
DURATION OF EXPERIMENT (DAYS)

Fig. 6(b)

The final average length and final average weight gain in postlarvae fed 22% ration size at five feeding frequencies are shown in Fig. 6 and Fig. 7. As observed earlier in the case of animals fed at 12% ration size, there was 81% and 24% increase in length in postlarvae fed once in the morning and two times respectively while there was not much difference in the other three groups. After 30 days of feeding, the final average length ranged from 3.7 cm to 5.4 cm respectively. Here too, percentage increase in weight (Table 10) was comparatively very high in the animals fed once in the morning (532%) and animals fed two times in the day (101) in comparision to the other three groups.

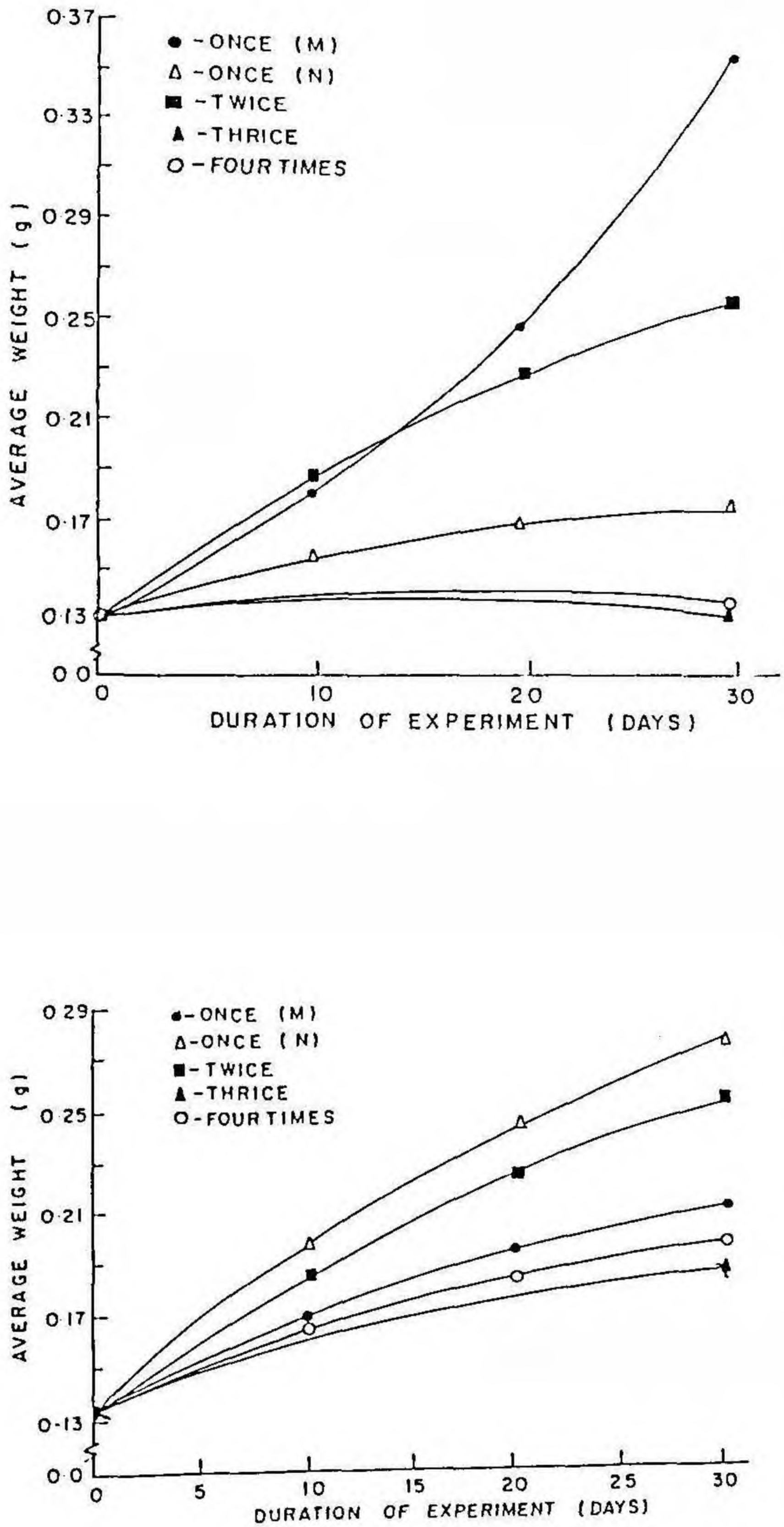
There was an increase in final average length of 2.50, 1.86, and 1.28 cm respectively in the case of postlarvae fed once in the morning, two times and four times at 32% ration size while there was only 0.55 cm and 0.89 cm increase in average length in the case of those fed once in the night and three times respectively (Fig. 6). Animals fed once in the morning gave the maximum increase in length of 84% followed by those fed twice a day at 63%. (Table 11).

Final average weight increased from 0.13 g to 0.82g and 0.595g in the animals fed once in the morning and twice daily (Fig.7) and this showed a 532% and 353% increase in body weight (Table 11).

Specific Growth Rate (SGR)

SGR has been applied generally in experiments with fish where growth is continuous. Its use with shrimp is justified on the assumption

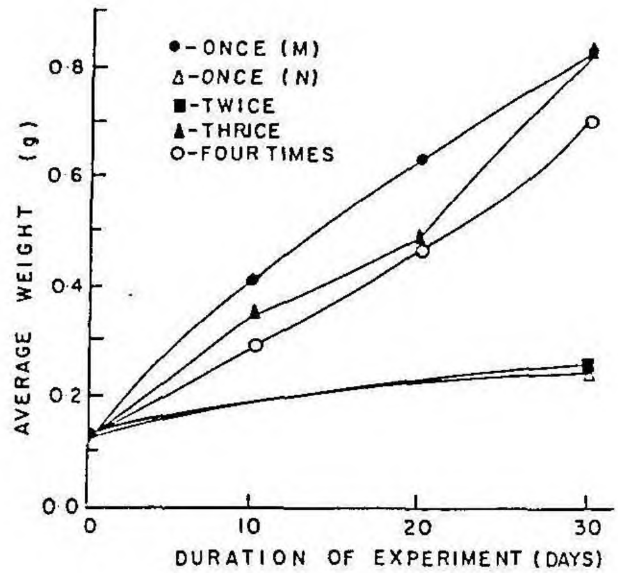
Fig. 7(a). Average increase in weight of P. indicus postlarvae fed at the 2% and 12% ration size.



0·37
0·33
0·29
0·25
0·21
0·17
0·13
0·0
● - ONCE (M)
Δ - ONCE (N)
■ - TWICE
▲ - THRICE
○ - FOUR TIMES
AVERAGE WEIGHT (g)
0
10
20
30
DURATION OF EXPERIMENT (DAYS)
0·29
0·25
0·21
0·17
0·13
0·0
●- ONCE (M)
Δ- ONCE (N)
■- TWICE
▲- THRICE
○- FOUR TIMES
AVERAGE WEIGHT (g)
0
5
10
15
20
25
30
DURATION OF EXPERIMENT (DAYS)

Fig. 7(a)

Fig.7(b). Average increase in weight of P. indicus postlarvae fed at the 22% and 32% ration size.


●-ONCE (M)
Δ-ONCE (N)
■-TWICE
▲-THRICE
O-FOUR TIMES
AVERAGE WEIGHT (g)
0·0
0·2
0·4
0·6
0·8
0
10
20
30
DURATION OF EXPERIMENT (DAYS)

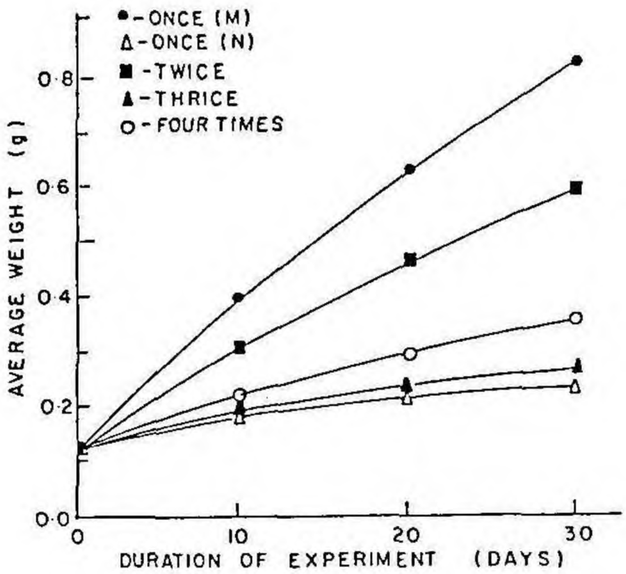

●-ONCE (M)
Δ-ONCE (N)
■-TWICE
▲-THRICE
O-FOUR TIMES
AVERAGE WEIGHT (g)
0·0
0·2
0·4
0·6
0·8
0
10
20
30
DURATION OF EXPERIMENT (DAYS)

Fig. 7(b)

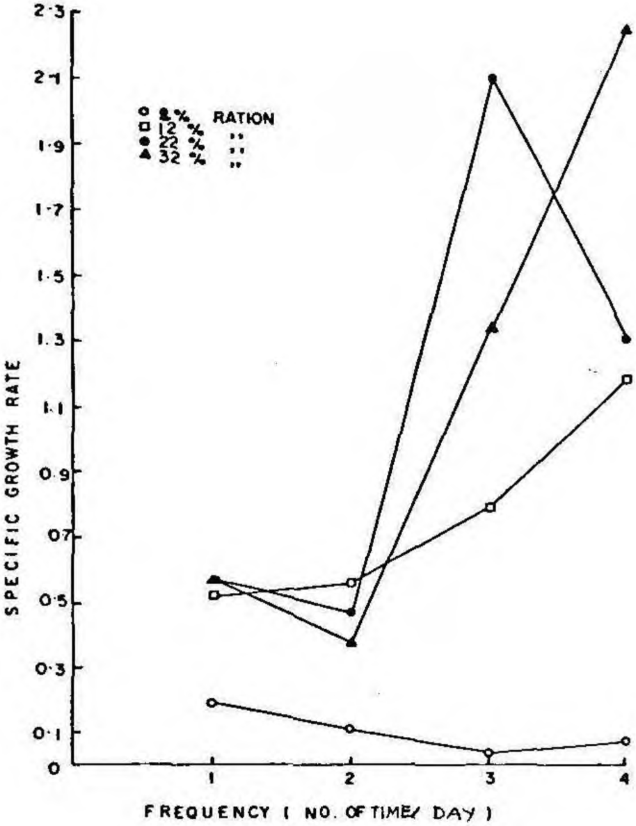
TABLE 10

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF <u>P. INDICUS</u> POSTLARVAE FED AT TWENTY TWO PERCENT RATION SIZE

Parameters	Frequency of Feeding				
	One Time		Two times	Three times	Four times
	Morning	Night			
% Increase in length	80.94	25.29	24.20	80.94	76.44
% Increase in weight	531.53	89.64	100.76	531.53	435.39
Survival (%)	89	86	79	71	86
S.G.R.	0.57	1.18	0.47	2.13	1.32
F.C.R.	2.29	1.72	3.71	1.10	1.46
P.E.R.	1.21	1.61	0.75	2.50	1.90
K_1%	43.67	58.14	26.95	90.91	68.49
K_2%	49.17	75.91	31.28	125.62	101.87

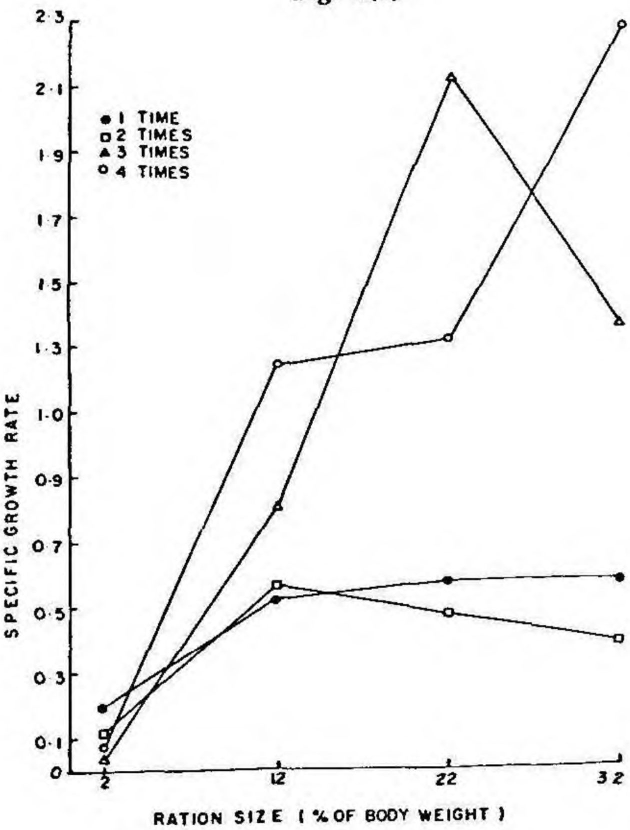
SGR - Specific Growth Rate; FCR-Food Conversion Ratio; PER-Protein Efficiency Ratio; K_1%-Gross Conversion Efficiency K_2%-Net Conversion Efficiency.

Fig. 8. Effect on specific growth rate of *P. indicus* postlarvae with change in
(a) feeding frequency
(b) ration size



o 2 % RATION
□ 12 %
● 22 % ,,
▲ 32 % ,,
SPECIFIC GROWTH RATE
FREQUENCY (NO. OF TIME/ DAY)

Fig. 8(a)



● 1 TIME
□ 2 TIMES
▲ 3 TIMES
○ 4 TIMES
SPECIFIC GROWTH RATE
RATION SIZE (% OF BODY WEIGHT)

Fig. 8(b)

that the population means have a smoothing effect on the intermittent growth pattern caused by moulting. SGR in postlarvae fed at 2% ration size was comparatively poor ranging from a minimum of 0.032 in animals fed thrice a day to a maximum of 0.232 in animals fed once in the night. No significant variation could be seen in SGR as regards feeding frequency at this ration size ($P > 0.05$) (Fig. No. 8 ,Table No. 7).

At the 12% ration size, four times feeding resulted in SGR of 1.24 followed by 0.74 at one time night feeding Minimum SGR (0.52) was observed in the case of animals fed once in the morning. Here too, no significant variation could be detected between the different feeding frequencies (Fig. nos. 8, Table No. 9).

An SGR of 2.13 was obtained in postlarvae fed at 22% ration size thrice a day followed by 1.18 in the night and 1.32 in the case of animals fed four times. Animals fed once in the morning and twice daily gained comparatively poor SGR values of 0.57 and 0.47 respectively (Fig.No. 8) (Table 10).

The highest value observed for SGR (2.29) in the present study in the case of postlarvae was obtained by feeding animals 32% ration size 4 times a day. This was followed by SGR of 1.36 obtained in the case of animals fed three times a day and 1.11 in the case of animals fed once in the night (Fig. No.8 , Table 11). Feeding once in the morning and twice a day showed poor SGR values of 0.57 and 0.38 respectively.

TABLE 11

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF P. INDICUS POSTLARVAE FED AT THIRTY TWO PERCENT RATION SIZE

Parameters	Frequency of Feeding				
	One Time		Two times	Three times	Four times
	Morning	Night			
% Increase in length	84.14	18.59	62.55	29.90	43.03
% Increase in weight	531.69	84.62	353.17	103.50	174.49
Survival (%)	75	71	75	57	71
S.G.R.	0.57	1.11	0.38	1.36	2.29
F.C.R.	3.89	2.09	5.12	2.33	1.18
P.E.R.	0.71	1.33	0.54	1.19	2.35
K_1%	25.71	47.85	19.53	42.92	84.75
K_2%	28.66	56.33	22.81	53.85	110.65

SGR - Specific Growth Rate; FCR-Food Conversion Ratio;

PER - Protein Efficiency Ratio; K_1%-Gross Conversion Efficiency

K_2% - Net Conversion Efficiency

TABLE 12

ANALYSIS OF VARIANCE FOR SPECIFIC GROWTH RATE OF POSTLARVAE.

Source	Degrees of freedom	Sum of Squares	Mean Square	F Value	Remarks
Ration	3	3.41	1.14	6.24	Hi sig (1%)
Frequency	4	2.22	0.56	3.05	N.S.
Error	12	2.19	0.18		
Total	19	7.82			

Though the different feeding frequencies failed to reflect any significant variation ($P > 0.05$) in the SGR of postlarvae, ration size viz. 2%, 12%, 22%, and 32% was found to have a significant influence on the SGR ($P < 0.01$) with 2% ration giving the best values(Table 12)

Food Conversion Ratio (F.C.R.) and Protein Efficiency Ratio(P.E.R.)

For 2% ration size the best (lowest) feed conversion ratio of 1.34 (Table 7) was obtained in the case of post larvae fed once in the night followed by animals fed once in the morning (1.74) and two times daily (1.83). Protein efficiency ratios followed the same trend being highest 2.07 (best) in the case of animals fed once in the night followed by 1.59 for animals fed once in the morning and 1.52 for animals fed twice a day. Animals fed 2% ration size in three divided doses gave the poorest FCR (8.18) and PER (0.34) values.

In the case of postlarvae fed 12% ration size the best FCR of 1.09 was obtained with a feeding frequency of four times followed by one time morning feeding (1.41) and two time feeding (1.49). One time feeding at night resulted in a very high (poor) FCR of 6.02 for this ration size (Table 9). The same was the pattern observed in the case of PER with the best value of 2.55 being obtained in the case of postlarvae fed the 12% ration four times a day, followed by one time morning feeding (1.97) and two times feeding (1.86) respectively (Table 9). As in the case of FCR, animals fed once a day at night yielded a very low PER value of 0.461.

Feeding postlarvae at a ration size of 22% of the body weight three times a day yielded the best FCR of 1.1 followed by 1.46 in animals fed four times a day and 1.72 in animals fed once in the night (Table 10). One time morning feeding and two times feeding gave comparatively poor FCR values of 2.29 and 3.71 respectively. The best PER value of 2.5 was again observed in animals fed the 22% ration in three divided doses and the poorest value of 0.75 in the animals fed twice daily (Table 10).

At the 32% ration size an FCR of 1.18 was obtained in animals fed four times daily (Table 11). More or less similar values for FCR of 2.09 and 2.33 were obtained with groups fed once in the night and three times respectively, while comparatively poorer (higher) values were obtained in animals fed once in the morning (3.89) and two times (5.12) respectively. At this ration size the best PER value of 2.35 was obtained in the case of animals fed four times daily and the poorest value of 0.54 in animals fed twice a day (Table 11).

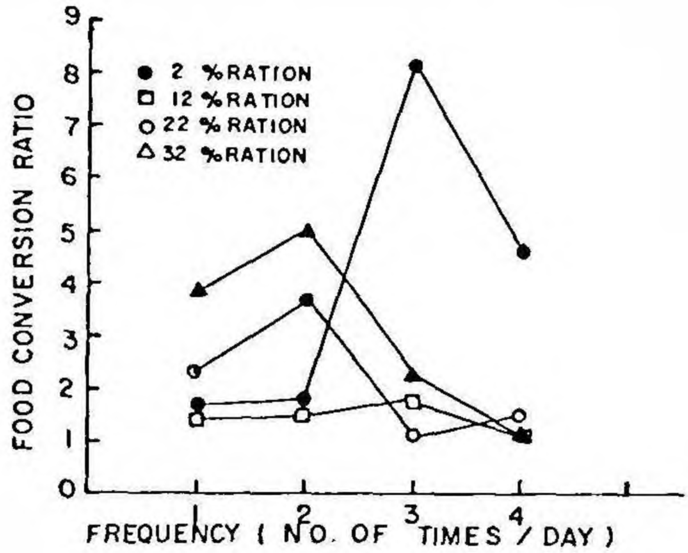
However, statistically no significance could be detected either between the ration sizes or the feeding frequencies with regard to both FCR and PER.

The FCR and PER of the different groups are presented in Tables 7,9,10 and 11 and graphically shown in Figs. 9 and 10. The values of

Fig. 9. Effect on feed conversion ratio of P. indicus postlarvae with change in

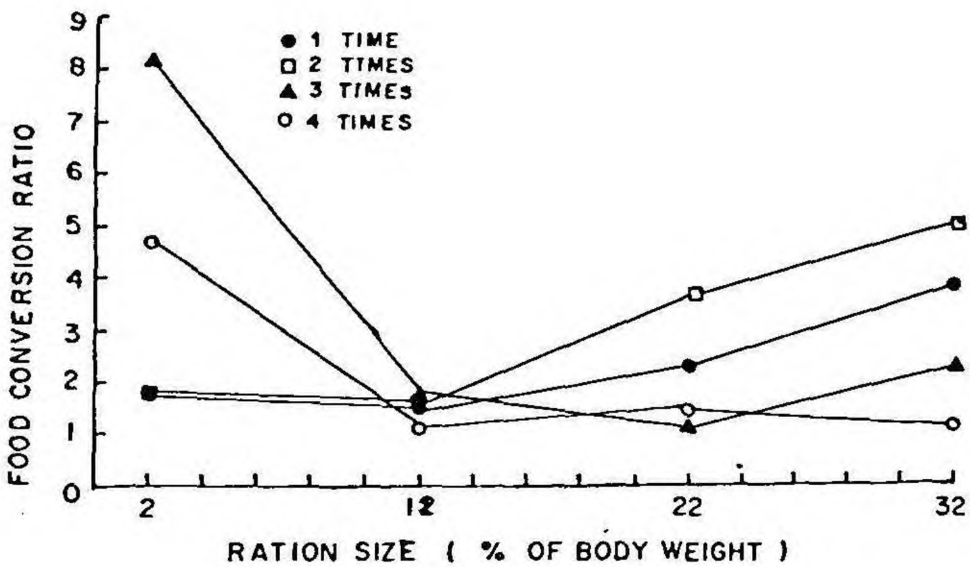
(a) feeding frequency

(b) ration size.



FOOD CONVERSION RATIO
● 2 % RATION
□ 12 % RATION
○ 22 % RATION
△ 32 % RATION
FREQUENCY (NO. OF TIMES / DAY)

Fig. 9(a)



FOOD CONVERSION RATIO
● 1 TIME
□ 2 TIMES
▲ 3 TIMES
○ 4 TIMES
RATION SIZE (% OF BODY WEIGHT)

Fig. 9(b)

Fig. 10. Effect on protein efficiency ratio of P. indicus postlarvae with change in

(a) feeding frequency

(b) ration size.

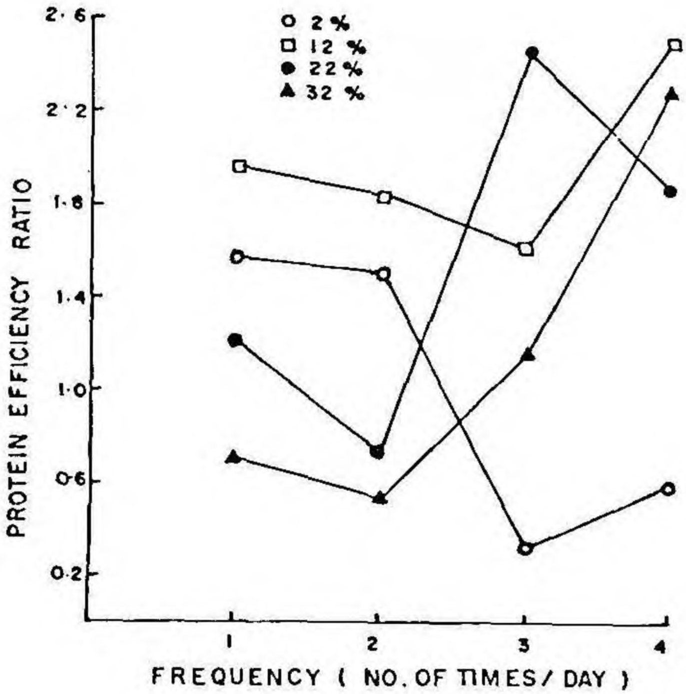


Fig. 10(a)

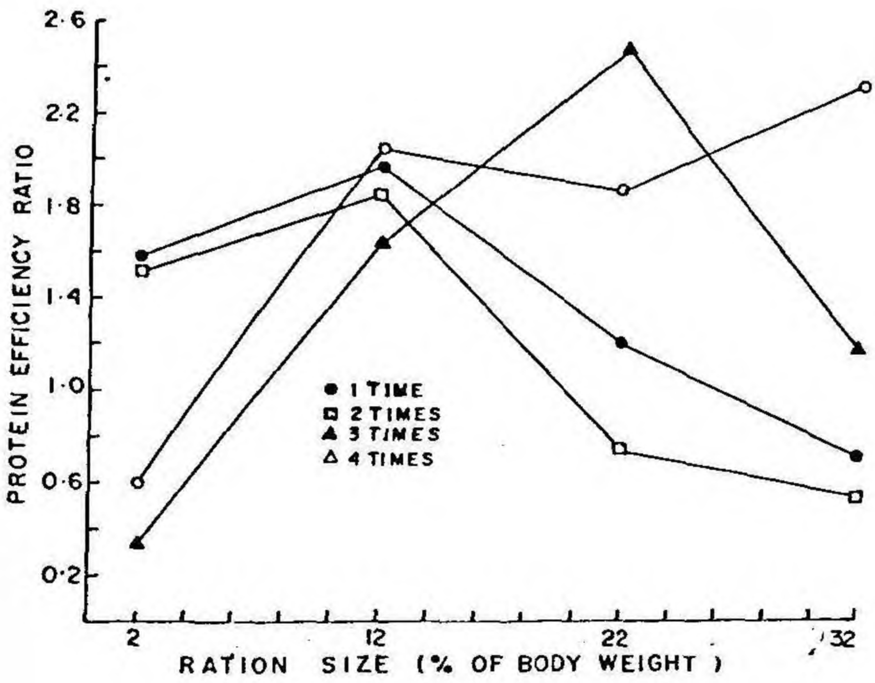


Fig. 10(b)

FCR ranged from 1.1 to 8.18 and no significant difference could be found among the different treatments.

Gross Conversion Efficiency (K_1%) and Net Conversion Efficiency (K_2%)

The relative deployment of food may be expressed as the coefficient of gross efficiency K_1 (Ivlev, 1945) and is closely related to FCR being essentially its inverse. The gross conversion efficiency of the different groups is shown in Tables 7,9,10 and 11. K_1 increased from 75% to92% (4 times feeding) with increase in ration size from 2 to 12%. At the 22% level, K_1 was 91% at a feeding frequency of thrice a day. Thereafter a decline to 85% was observed in the K_1 value with increase in ration size tc 32% body weight. However, this increase in K_1 observed with change in ration size was not significantly different ($P > 0.05$) as also was the case with regard to frequency of feeding.

Net efficiency (K_2) is the efficiency with which an animal utilises for growth the part of its rations that exceeds its maintenance ration. K_2 is always higher than K_1. K_2 values observed at the different ration sizes and different feeding frequencies are shown in Tables 7,9,10 and 11. Maximum K_2 value of 147% was obtained with 12% ration size and four times feeding. A slightly lower value of 126% was obtained at 22% ration size with three times feeding. However, no statistically significant variation could be detected in the K_2 values either with varying ration size or with frequency of feeding in postlarvae of P. indicus.

Fig. 11. Specific growth, G, of *Penaeus indicus* postlarvae fed at the varying ration levels and feeding frequeny.
(o - fed two times per day; Δ - fed three times per day; × - fed four times per day)

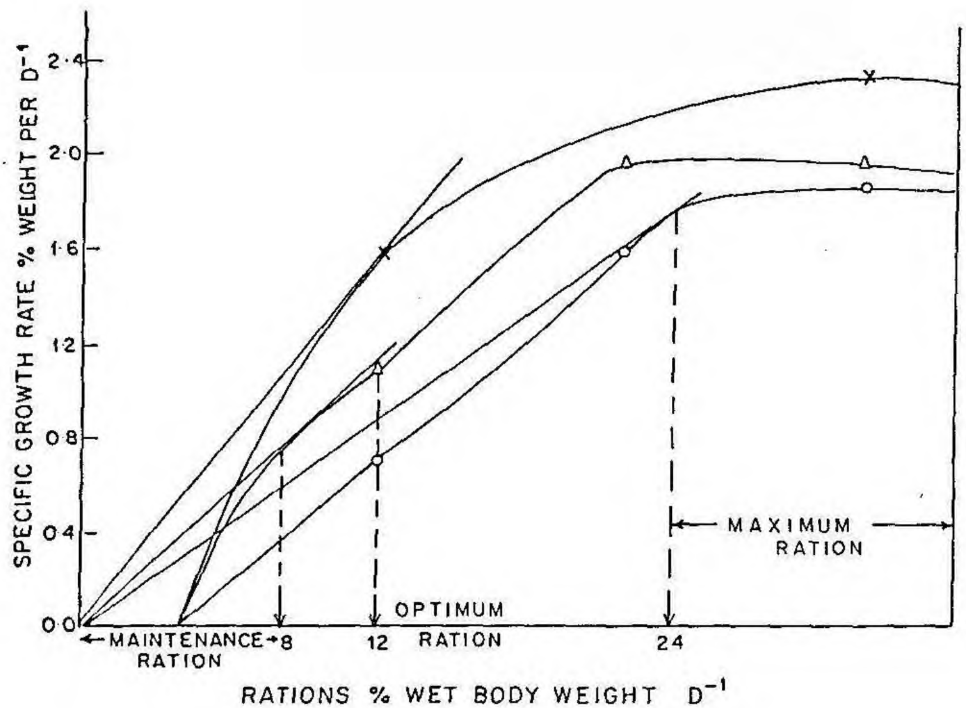

SPECIFIC GROWTH RATE % WEIGHT PER D^{-1}
2·4
2·0
1·6
1·2
0·8
0·4
0·0
MAXIMUM RATION
OPTIMUM RATION
MAINTENANCE RATION
8
12
24
RATIONS % WET BODY WEIGHT D^{-1}

Fig. 11

Optimum Ration size for postlarvae:

Postlarvae fed four times daily increased in weight more rapidly and utilized their food more efficiently than at the other feeding frequencies. The optimum ration was calculated at 12% of the wet body weight per day. At higher rations specific growth rate declined. Though starved controls were maintained, the lower regimes of the curves could not be defined and maintenance rations estimated accurately due to mortality and cannibalism. Rations below 8% were termed maintenance rations and those above 24% as maximum rations. (Fig 11.)

Juveniles:

Juveniles of Penaeus indicus were fed at four different ration sizes and four different feeding frequencies on an experimental basis to study the combined effects of ration size and feeding frequency. The four ration sizes taken were 2%, 8%, 12% and 16% while the feeding frequencies were the same as in the case of postlarva excepting for one time night feeding which was deleted. The experiment lasted for 30 days and the data obtained is elaborated below. The initial average length for the animals in this group ranged from 5.65 cm to 6.93 cm while initial average weight ranged from 0.99 g to 1.72 g respectively. During the 30 day feeding experiments, juvenile P. indicus readily accepted the feeds. However, survival was comparatively lower than that observed in the case of postlarvae ranging from 33% to 83% and was attributed to the frequent moulting and cannibalistic tendencies which resulted in an overall poor growth performance (Fig. 12). Variance in ration size and feeding

Fig. 12. Effect on survival of *P. indicus* juvenile with change in

(a) feeding frequency

(b) ration size.

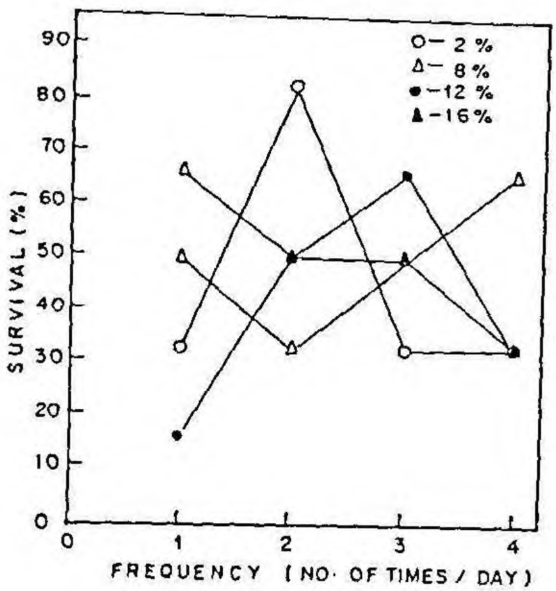


Fig. 12(a)

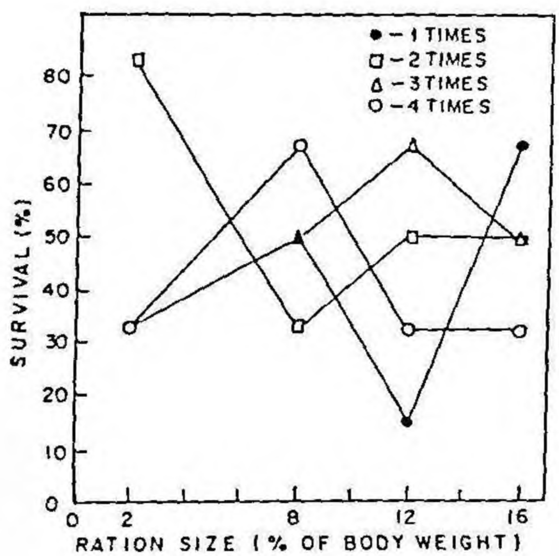


Fig. 12(b)

TABLE 13

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF *P. INDICUS* JUVENILES FED AT TWO PERCENT RATION SIZE.

Parameters	Frequency of Feeding			
	One Time	Two times	Three times	Four times
% Increase in length	5.43	16.46	11.11	1.85
% Increase in weight	-13.93	51.06	74.85	71.82
Survival (%)	33	83	33	33
S.G.R.	-0.91	1.80	0.40	2.46
F.C.R.	-	4.32	1.45	1.56
P.E.R.	-	0.67	3.67	7.75
K_1%	-	23.17	68.92	64.35
K_2%	-	25.21	134.93	124.72

SGR - Specific Growth Rate; FCR - Food Conversion Ratio; PER - Protein Efficiency Ratio; K_1% - Gross Conversion Efficiency K_2% - Net Conversion Efficiency.

frequency failed to reflect any significant difference with regard to survival ($P > 0.05$). Growth responses under the varying ration sizes and feeding frequencies is given in Tables 13, 14, 15, 16 and graphically shown in Figs. 12 to 17.

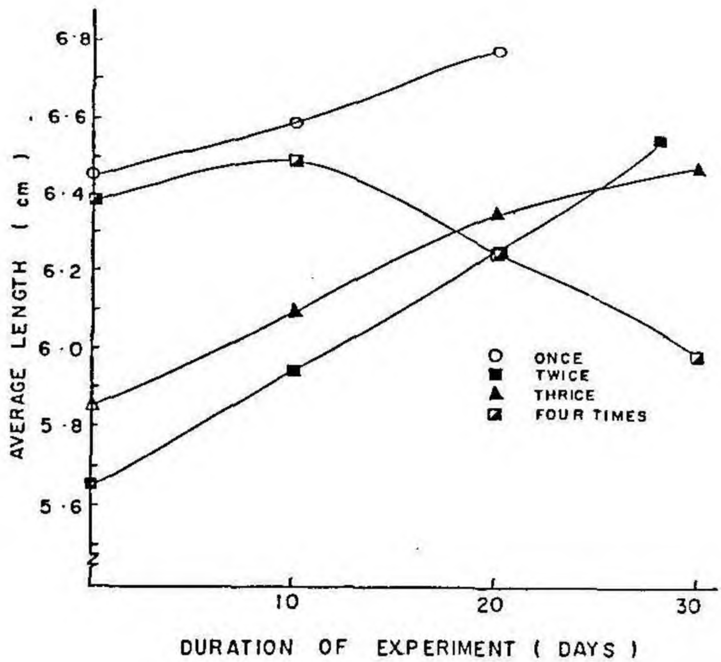
Length and Weight:

The final average length and percentage increase in length are given in Fig. 13 and Tables 13, 14, 15 and 16. There was not much significant variation ($P > 0.05$) in the final average length of juvenile P. indicus with regard to ration size and feeding frequency. Final average length ranged from 6 cm to 7.53 cm. The highest obtained was 16% in the form of % increase in length in this group. As regards the final average weight gain, animals maintained at the 2% and 8% ration sizes showed higher values in comparision to those maintained at 12% and 16% ration size (Fig 14). Maximum % increase in weight of 75 and 72% respectively were observed in animals fed 2% ration size three times and four times a day. (Table 13)

Specific Growth Rate (S.G.R)

SGR observed on the four ration sizes and feeding frequencies are given in Tables 13, 14, 15 and 16 and graphically in Fig. 15. Though no statistically significant differences ($P > 0.05$) could be observed in the SGR with regard to ration size and feeding frequency in juvenile P. indicus the values obtained were however higher compared to those obtained in the case of postlarvae. A maximum SGR of 3.32 was recorded at

Fig. 13(a) Average increase in length of P. indicus juveniles fed at the 2% and 8% ration size.


6·8
6·6
6·4
6·2
6·0
5·8
5·6
AVERAGE LENGTH (cm)
10
20
30
DURATION OF EXPERIMENT (DAYS)
ONCE
TWICE
THRICE
FOUR TIMES

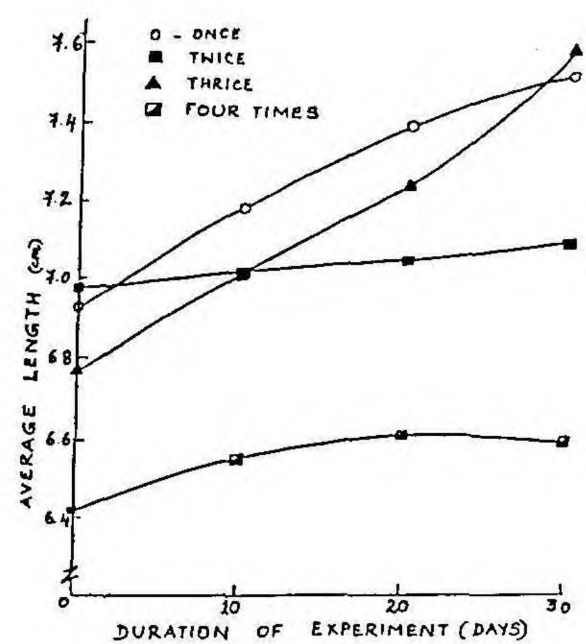
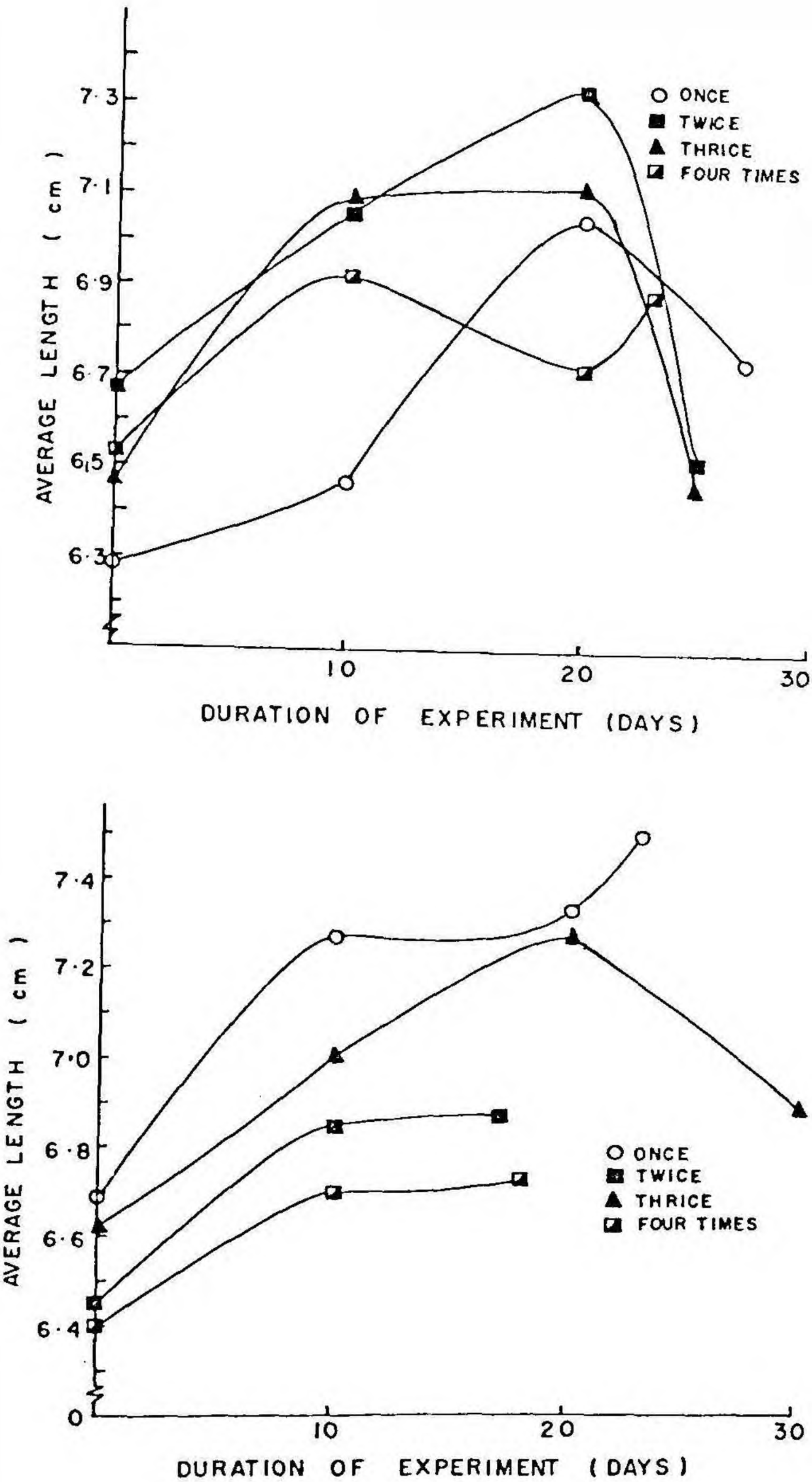

7.6
7.4
7.2
7.0
6.8
6.6
6.4
AVERAGE LENGTH (cm)
0
10
20
30
DURATION OF EXPERIMENT (DAYS)
O - ONCE
TWICE
THRICE
FOUR TIMES

Fig. 13(a)

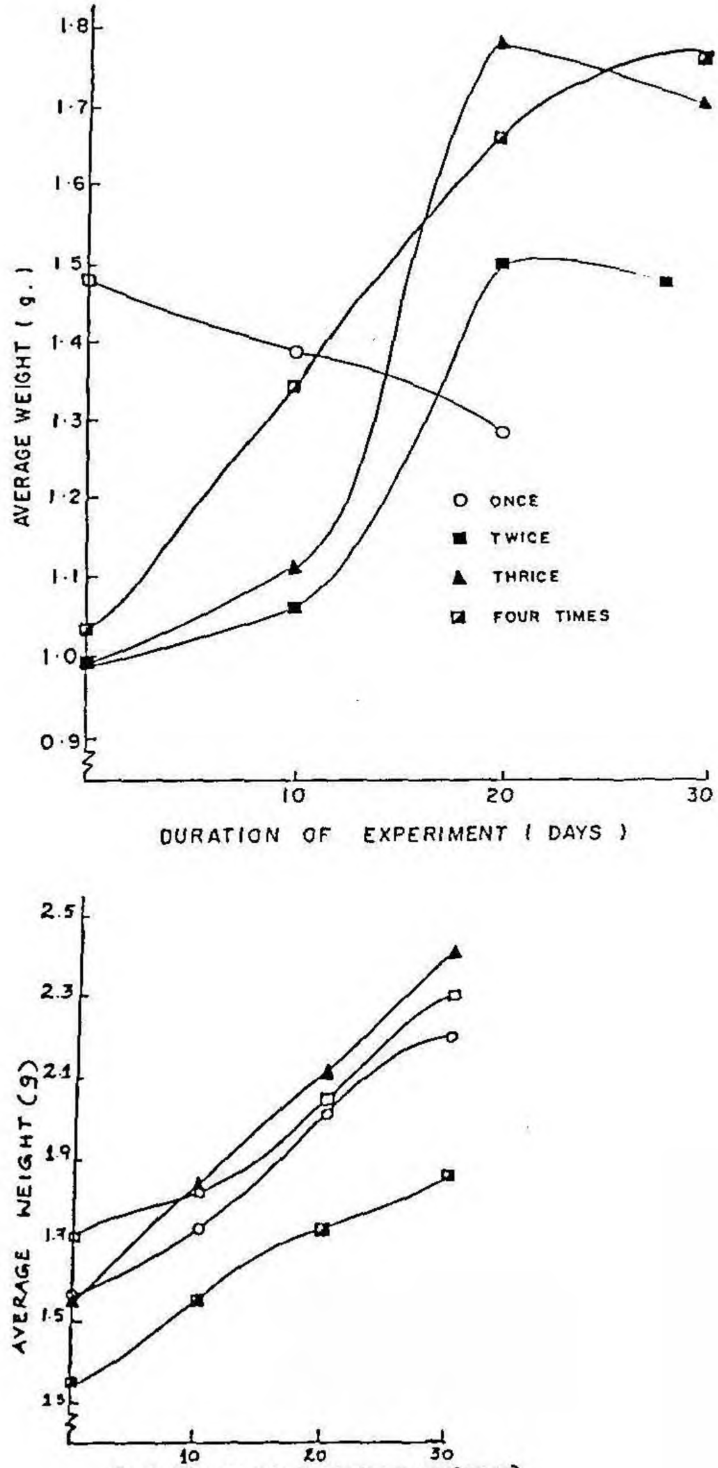
Fig. 13(b) Average increase in length of P. indicus juveniles fed at the 16% and 12% ration size.



7·3
7·1
6·9
6·7
6.5
6·3
AVERAGE LENGTH (cm)
10
20
30
DURATION OF EXPERIMENT (DAYS)
ONCE
TWICE
THRICE
FOUR TIMES
7·4
7·2
7·0
6·8
6·6
6·4
0
AVERAGE LENGTH (cm)
10
20
30
DURATION OF EXPERIMENT (DAYS)
ONCE
TWICE
THRICE
FOUR TIMES

Fig. 13(b)

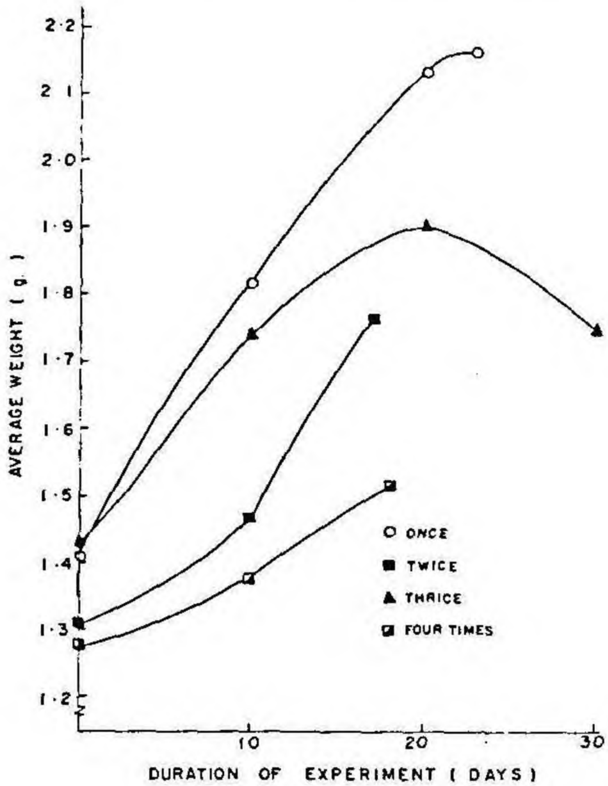
Fig. 14(a) Average increase in weight of _P. indicus_ juveniles fed at the 2% and 8% ration size.



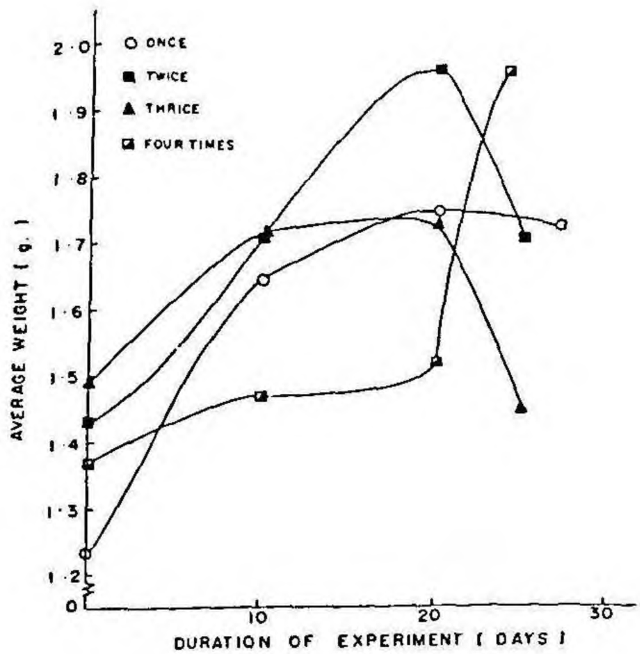
1·8
1·7
1·6
1·5
1·4
1·3
1·2
1·1
1·0
0·9
AVERAGE WEIGHT (g.)
10
20
30
DURATION OF EXPERIMENT (DAYS)
ONCE
TWICE
THRICE
FOUR TIMES
2.5
2.3
2.1
1.9
1.7
1.5
1.3
AVERAGE WEIGHT (g)
10
20
30
DURATION OF EXPERIMENT (DAYS)

Fig. 14(a)

Fig. 14(b) Average increase in weight of P. indicus juveniles fed at the 12% and 16% ration size.



2·2
2·1
2·0
1·9
1·8
1·7
1·6
1·5
1·4
1·3
1·2
AVERAGE WEIGHT (g.)
10
20
30
DURATION OF EXPERIMENT (DAYS)
ONCE
TWICE
THRICE
FOUR TIMES



2·0
1·9
1·8
1·7
1·6
1·5
1·4
1·3
1·2
0
AVERAGE WEIGHT (g.)
10
20
30
DURATION OF EXPERIMENT (DAYS)
ONCE
TWICE
THRICE
FOUR TIMES

Fig. 14(b)

Fig. 15. Effect on specific growth rate of P. indicus juveniles with change in

(a) feeding frequency

(b) ration size

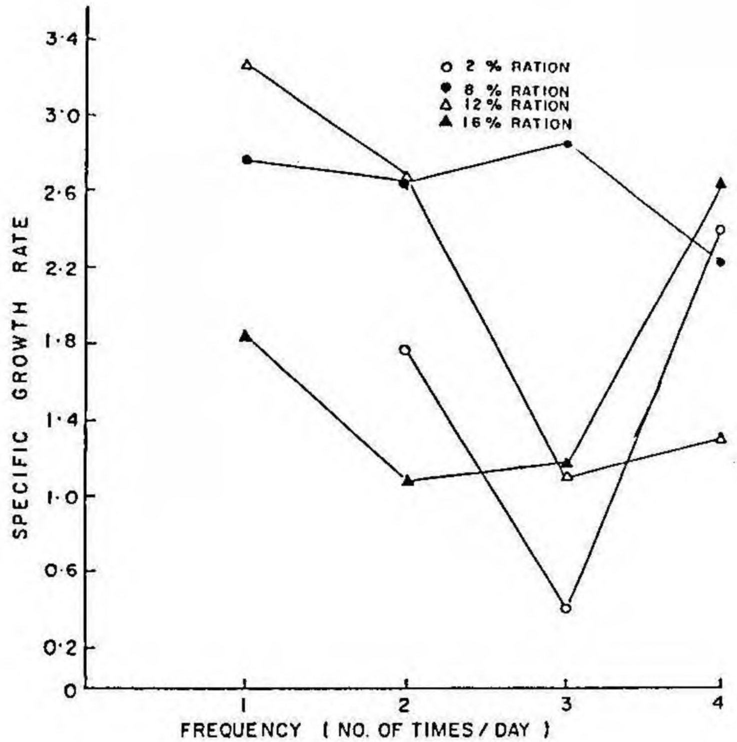


Fig. 15(a)

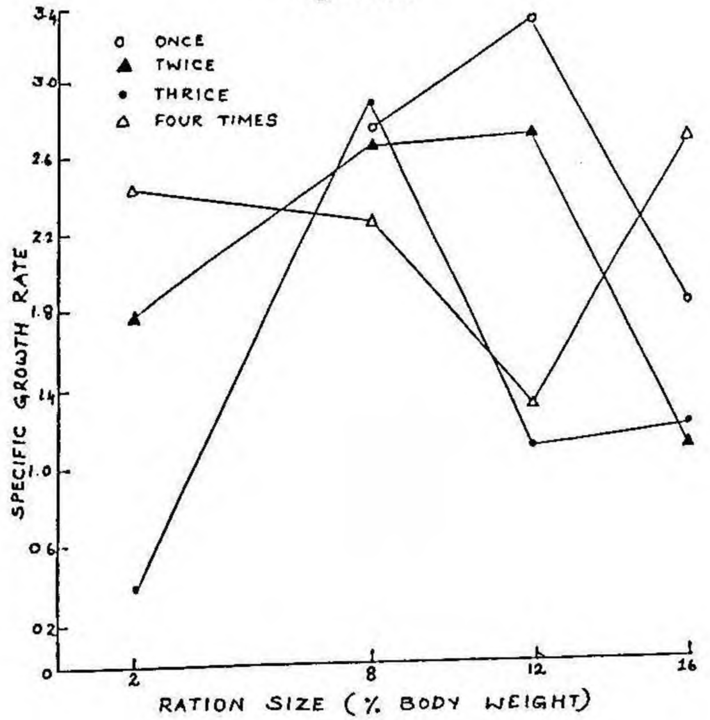


Fig. 15(b)

TABLE 14

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF *P. INDICUS* JUVENILES FED AT EIGHT PERCENT RATION SIZE

	Frequency of Feeding			
Parameters	One Time	Two times	Three times	Four times
% Increase in length	8.65	1.67	12.43	2.78
% Increase in weight	40.72	34.41	56.13	39.05
Survival (%)	50	33	50	67
S.G.R.	2.78	2.69	2.9	2.29
F.C.R.	3.38	3.63	1.52	4.90
P.E.R.	0.84	0.80	1.92	0.59
K_1%	29.60	27.59	65.79	20.40
K_2%	34.65	28.96	77.28	21.26

SGR - Specific Growth Rate; FCR - Food Conversion Ratio;
PER - Protein Efficiency Ratio; K_1% - Gross Conversion Efficiency
K_2% - Net Conversion Efficiency.

the 12% level with one time feeding, which was closely followed by a value of 2.9 observed in animals maintained at the 8% ration level with three times feeding.

Food conversion Ratio (FCR) and Protein Efficiency Ratio (PER)

Results on FCR and PER obtained after feeding juvenile P. indicus for 30 days with the varying ration sizes at different feeding frequencies are given in Tables 13, 14 15 and 16 and graphically in Figs. 16 and 17. FCR values were comparatively lower (better) in the 2% and 8% ration size and ranged from 1.52 in the case of animals fed the 8% ration three times a day to 4.9 in the case of animals fed 8% ration four times a day. 12% and 16% ration size gave higher (poorer) FCRs ranging from 3.59 to 11.78. The FCRs statistically showed highly significant variations ($P < 0.01$) with regard to ration size. (Table 17). PER values (Table 13, 14 15 and 16; Fig. 17) though not statistically significant with regard to either ration size or feeding frequency followed a similar pattern observed in the case of FCR with animals maintained at 2% ration size fed 4 times a day giving the highest PER value of 7.8. PER values in the 12% and 16% ration sizes were comparatively very low ranging from 0.26 to 1.00.

Gross Conversion Efficiency (K_1%) and Net Conversion Efficiency (K_2%)

Conversion of feed consumed/assimilated into growth was more efficient in juvenile shrimp maintained at the 2% and 8% ration sizes in comparision to those maintained at 12% and 16% ration sizes (Tables 13,14,15 and 16). Highest K_1 value of 69% and highest K_2 value of

Fig. 16. Effect on food conversion ratio of _P. indicus_ juveniles with change in

(a) feeding frequency

(b) ration size

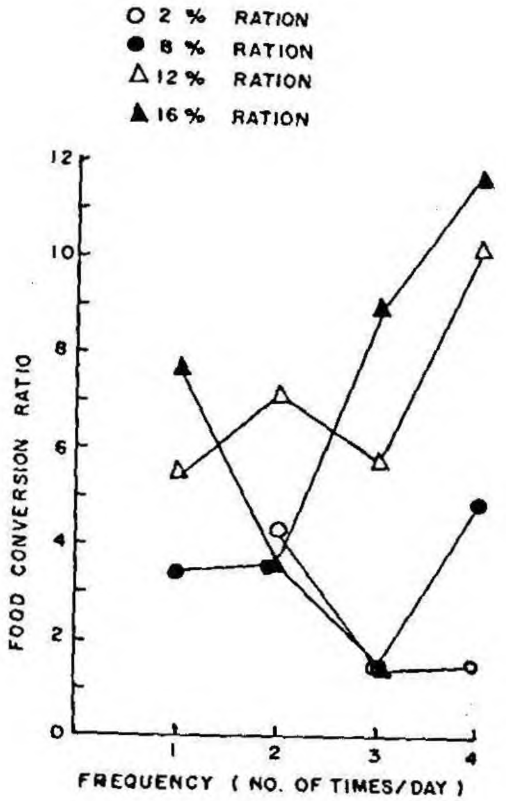


Fig. 16(a)

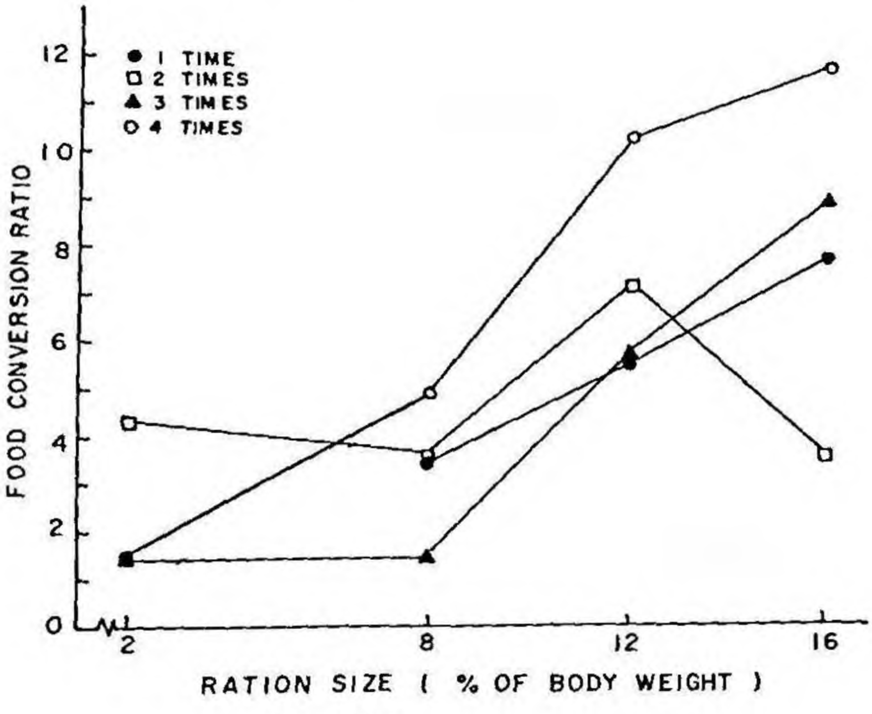


Fig. 16(b)

Fig. 17. Effect on protein efficiency ratio of P. indicus juveniles with change in

(a) feeding frequency

(b) ration size.

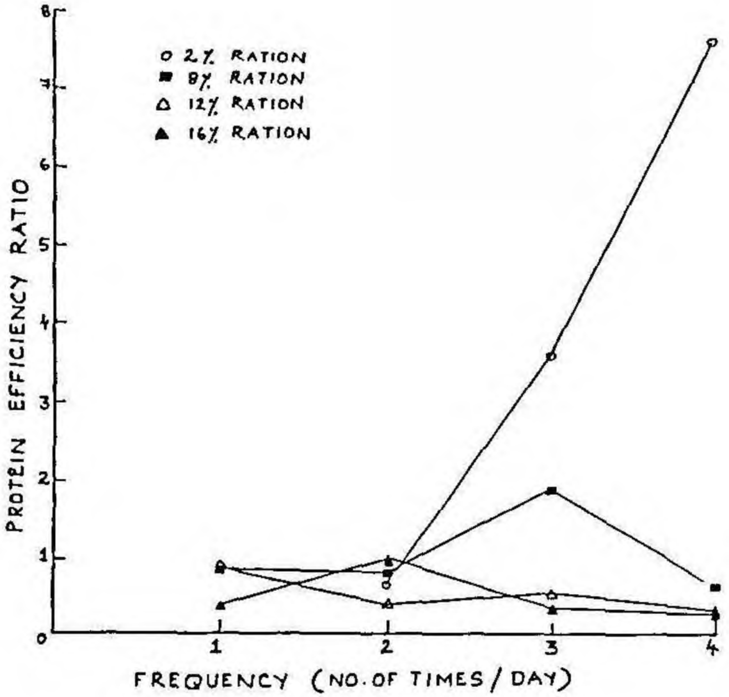


Fig. 17(a)

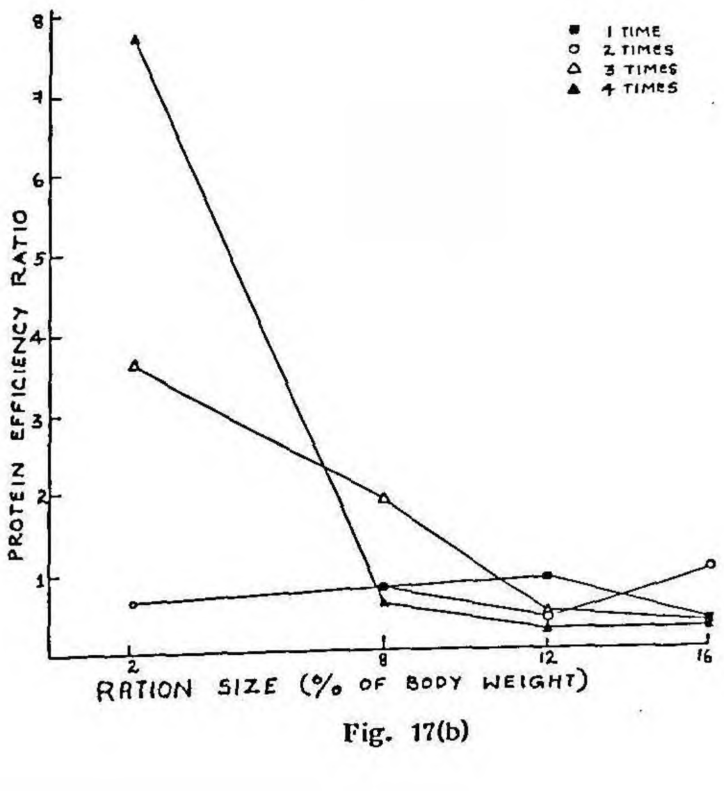


Fig. 17(b)

TABLE 15

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF P. INDICUS JUVENILES FED AT TWELVE PERCENT RATION SIZE.

	Frequency of Feeding			
Parameters	One Time	Two times	Three times	Four times
% Increase in length	12.22	6.46	3.98	9.82
% Increase in weight	53.99	35.21	23.28	18.67
Survival (%)	16	50	67	33
S.G.R.	3.32	2.71	1.11	1.33
F.C.R.	5.47	7.22	5.83	10.28
P.E.R.	0.89	0.40	0.54	0.28
K_1%	18.28	13.85	17.15	9.73
K_2%	33.50	18.00	19.36	10.51

SGR - Specific Growth Rate; FCR - Food Conversion Ratio;
PER - Protein Efficiency Ratio; K_1% - Gross Conversion Efficiency
K_2%- Net Conversion Efficiency.

TABLE 16

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF *P. INDICUS* JUVENILES FED AT SIXTEEN PERCENT RATION SIZE

Parameters	Frequency of Feeding			
	One Time	Two times	Three times	Four times
% Increase in length	7.43	10.25	10.31	5.62
% Increase in weight	40.60	19.20	16.03	45.37
Survival (%)	67	50	50	33
S.G.R.	1.85	1.10	1.20	2.70
F.C.R.	7.68	3.59	8.95	11.78
P.E.R.	0.38	1.00	0.35	0.26
K_1%	13.02	27.86	11.17	8.49
K_2%	13.76	38.44	12.60	9.20

SGR - Specific Growth Rate; FCR - Food Conversion Ratio;

PER - Protein Efficiency Ratio; K_1% - Gross Conversion Efficiency

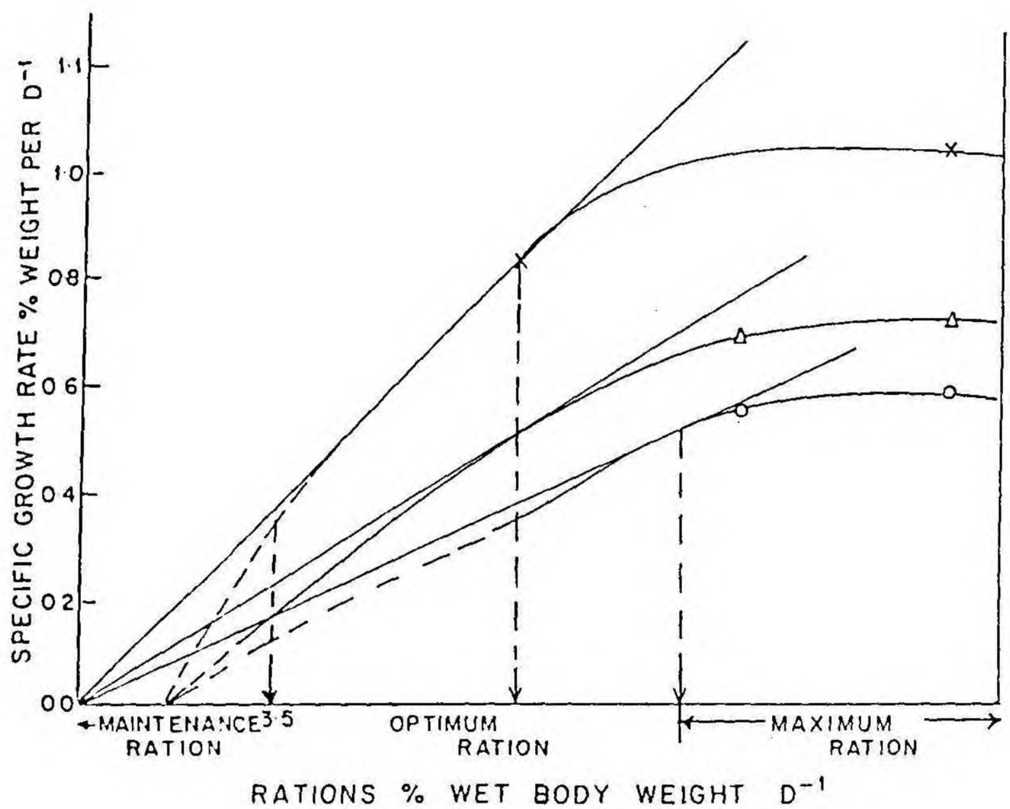
K_2%- Net Conversion Efficiency.

TABLE 17

ANALYSIS OF VARIANCE FOR FOOD CONVERSION RATIO

Source	Degree of Freedom	Sum of Squares	Mean Square	F value	Remarks
Ration	3	112.92	37.64	7.18	Hi Sig (1%)
Frequency	3	18.77	6.26	1.19	N.S.
Error	9	47.21	5.246		
Total	15	178.90			

Fig. 18. Specific growth, G, of Penaeus indicus juveniles fed at the varying ration levels and feeding frequency.
(o - fed two times per day; Δ - fed three times per day; x - fed four times per day)



SPECIFIC GROWTH RATE % WEIGHT PER D⁻¹
1·1
1·0
0·8
0·6
0·4
0·2
0·0
MAINTENANCE RATION
3·5
OPTIMUM RATION
MAXIMUM RATION
RATIONS % WET BODY WEIGHT D⁻¹

Fig. 18

134% was obtained at the 2% ration size with three times feeding. This was followed by 64% for K_1 and 125% for K_2 with four times feeding at the same ration size. K_1 values in the case of animals maintained at 12% and 16% ration sizes though statistically not significant ($P > 0.05$) were comparatively poor and ranged from 8.49% to 27.86%, while K_2 values ranged from 9.2% to 38.4% respectively.

Optimum ration size for juveniles

The optimum ration calculated was 8% of the wet body weight per day. Rations above 11% were the maximum rations as, above this, specific growth rate declined. Here also cannibalism and mortality in the starved groups prevented the accurate calculation of the maintenance rations which were arbitrarily defined below 3.5% of the body weight. (Fig 18.)

ADULTS

Adult P. indicus were maintained at four ration sizes viz. 1%, 4%, 6% and 8% and four different feeding frequencies similar to those adopted in the case of juvenile P. indicus for a period of 30 days. The initial average length for the shrimp selected in this group ranged from 8.15 cm to 10.48 cm and initial average weight ranged from 4.05 g to 6.81 g respectively. The animals readily accepted the feed throughout the experimental duration and survival ranged from 50% to 100% in animals maintained on the 6% and 8% ration sizes. (Tables 18, 19, 20, 21 and Fig 19). Survival at 1% and 4% ration size was comparatively very poor ranging from 14%

TABLE 18

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF P. INDICUS ADULTS FED AT ONE PERCENT RATION SIZE

Parameters	Frequency of Feeding			
	One Time	Two times	Three times	Four times
% Increase in length	-17.27	-11.90	- 6.75	- 9.34
% Increase in weight	-46.63	-20.48	-32.41	-24.51
Survival (%)	25	75	67	25
S.G.R.	-11.66	-4.65	- 6.95	- 4.25
F.C.R.	-	-	-	-
P.E.R.	-	-	-	-
K_1%	-	-	-	-
K_2%	-	-	-	-

SGR - Specific Growth Rate; FCR - Food Conversion Ratio;
PER - Protein Efficiency Ratio; K_1% - Gross Conversion Efficiency
K_2% - Net Conversion Efficiency.

Fig. 19. Effect on survival of P. indicus adult with change in

(a) feeding frequency

(b) ration size

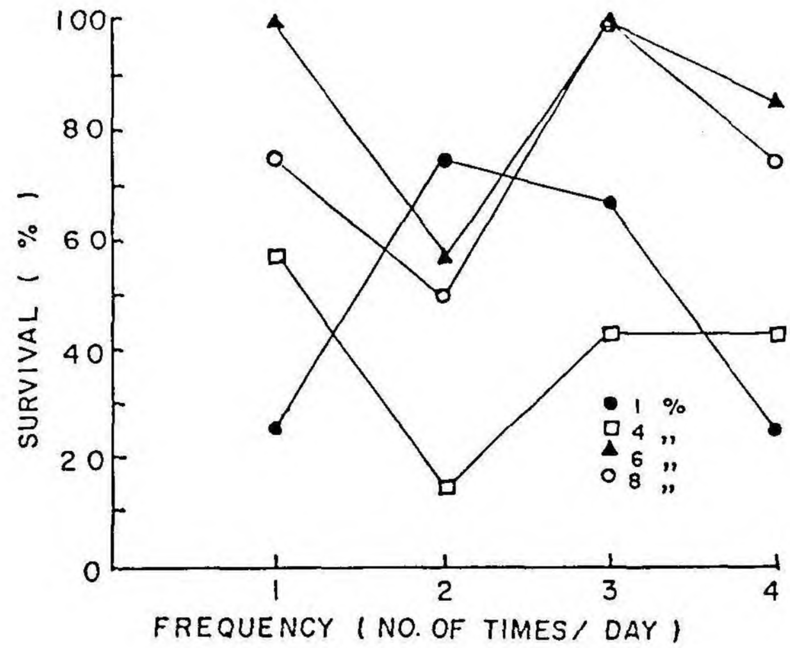


Fig. 19(a)

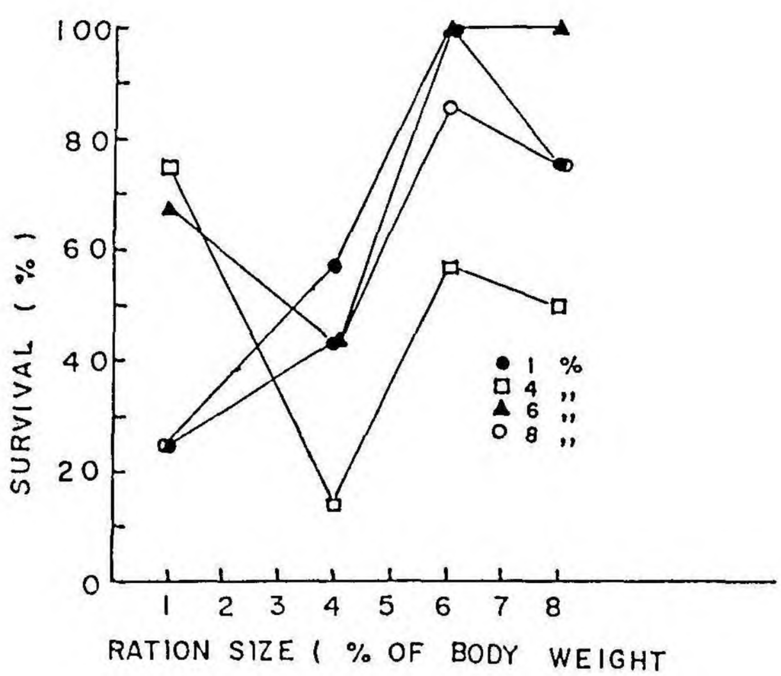


Fig. 19(b)

Fig. 20(a) Average increase in length of P. indicus adults fed at the 4% and 6% ration size.

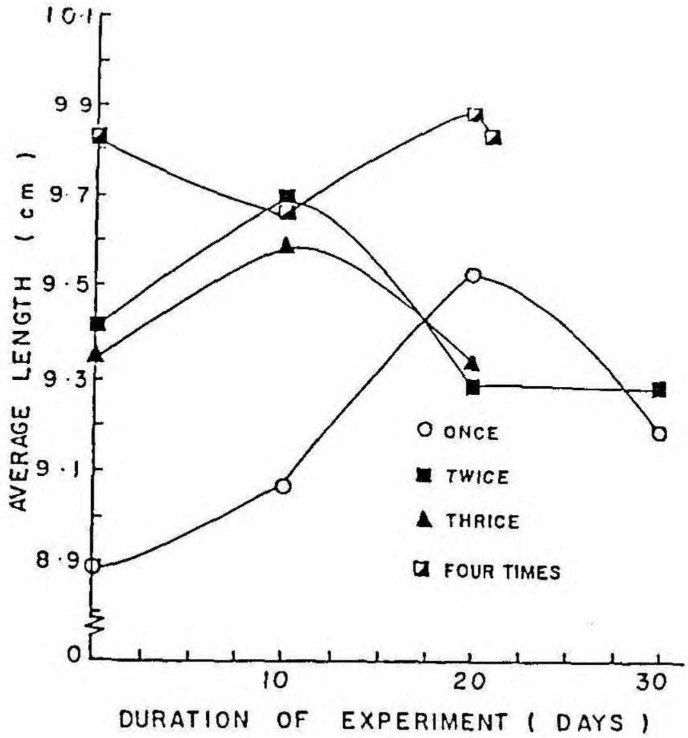


Fig. 20(a)

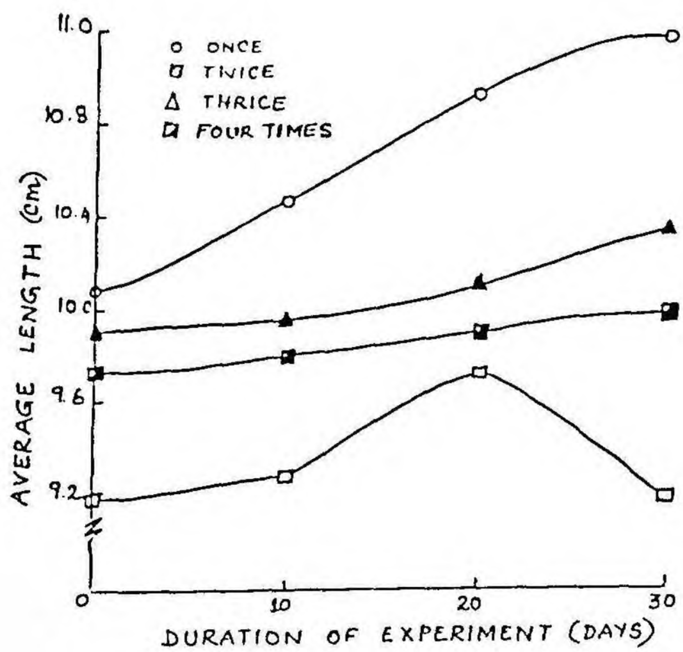
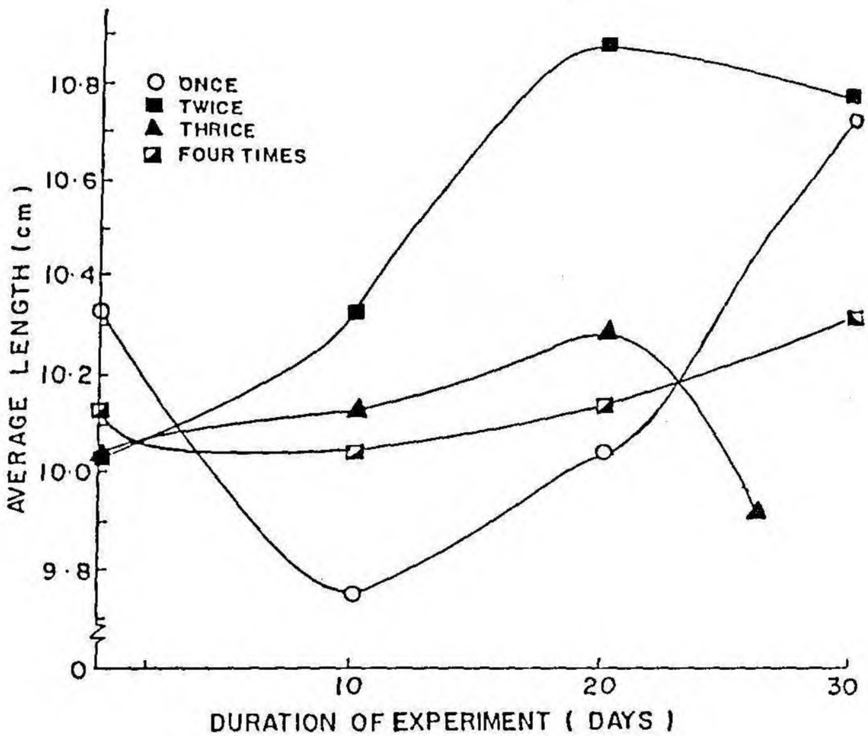


Fig. 20(b)

Fig. 20(b) Average increase in length of P. indicus adults fed at the 8% ration size.



O ONCE
TWICE
THRICE
FOUR TIMES
AVERAGE LENGTH (cm)
10·8
10·6
10·4
10·2
10·0
9·8
0
10
20
30
DURATION OF EXPERIMENT (DAYS)

Fig. 20(b)

Fig. 21. Average increase in weight of P. indicus adults fed at the 4% and 1% ration size.

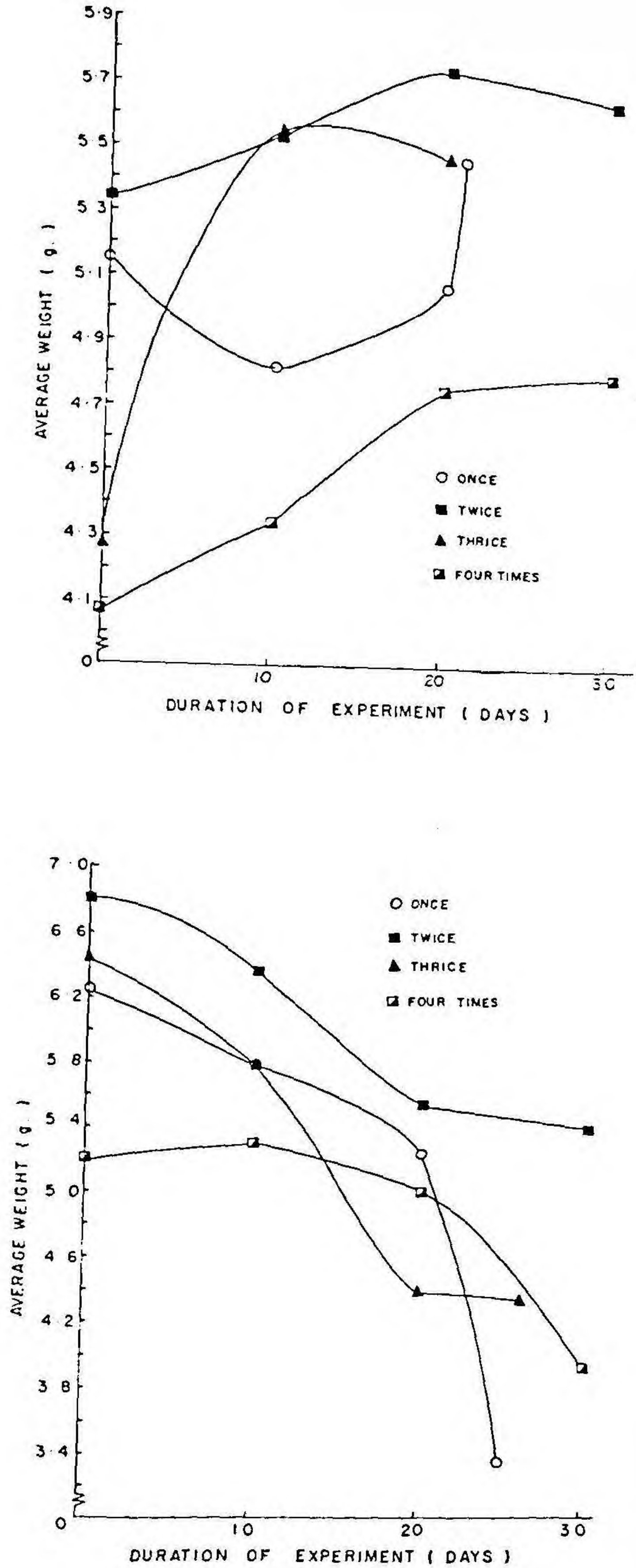
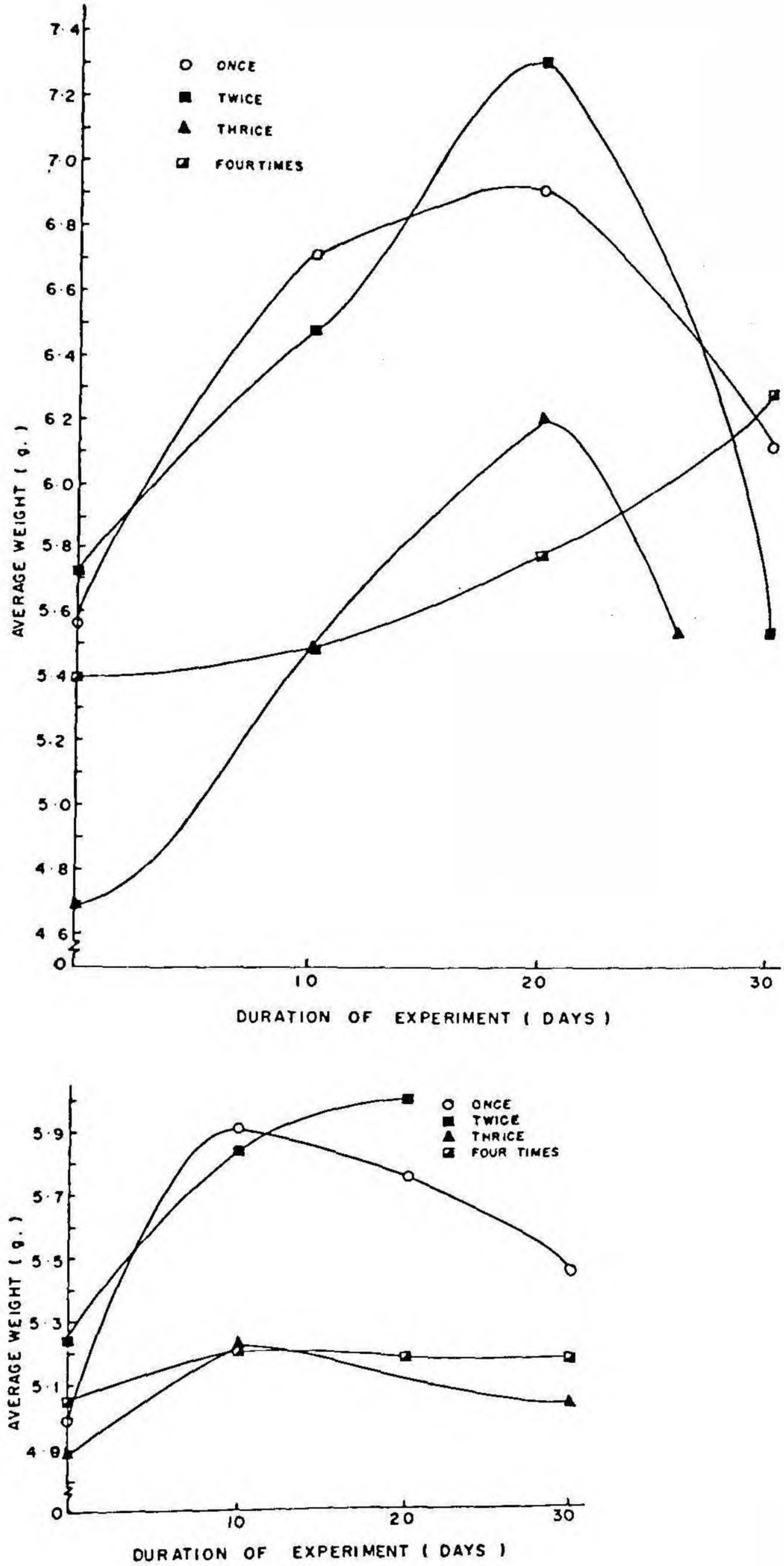

5·9
5·7
5·5
5·3
5·1
4·9
4·7
4·5
4·3
4·1
0
AVERAGE WEIGHT (g.)
10
20
30
DURATION OF EXPERIMENT (DAYS)
ONCE
TWICE
THRICE
FOUR TIMES
7·0
6·6
6·2
5·8
5·4
5·0
4·6
4·2
3·8
3·4
0
AVERAGE WEIGHT (g.)
10
20
30
DURATION OF EXPERIMENT (DAYS)
ONCE
TWICE
THRICE
FOUR TIMES

Fig. 21

Fig. 22. Average increase in weight of _P. indicus_ adults fed at the 8% and 6% ration size.



ONCE
TWICE
THRICE
FOURTIMES
AVERAGE WEIGHT (g.)
7·4
7·2
7·0
6·8
6·6
6·4
6·2
6·0
5·8
5·6
5·4
5·2
5·0
4·8
4·6
0
10
20
30
DURATION OF EXPERIMENT (DAYS)
ONCE
TWICE
THRICE
FOUR TIMES
AVERAGE WEIGHT (g.)
5·9
5·7
5·5
5·3
5·1
4·9
0
10
20
30
DURATION OF EXPERIMENT (DAYS)

Fig. 22

to 75%. Though frequency of feeding failed to elucidate any signifiant variation with regard to survival, ration size had a great impact on survival of adult animals ($P < 0.05$) (Table 22). Data on growth responses under the varying ration sizes and feeding frequenies are shown in Tables 18, 19, 20, 21.

Length and weight

Very poor growth response was observed in terms of increase in length and weight in animals maintained at 1% ration size. Heavy mortality and cannibalistic tendencies were observed in this group which were attributed to the very low quantity of feed and was not very much pronounced at the other three ration sizes (Table 19, 20, and 21 and Fig 20, 21 and 22. However, mortality at the 6% and 8% ration size with special reference to two times feeding was due to deterioration of water quality caused by feed.

A maximum of 12.5% as increase in length was observed in animals maintained at 6% ration level and fed twice a day, while maximum increase in weight of 28% was recorded at the 4% ration size at three times feeding. Ration size therefore was found to be statistially significant with regard to % increase in both length and weight ($P < 0.01$).

Specific Growth Rate (S.G.R.)

SGR was found to be greatly influenced by the ration size in adult _P. indicus_ as a highly statistically significant correlation was observed

TABLE 19

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF P. INDICUS ADULTS FED AT FOUR PERCENT RATION SIZE

Parameters	Frequency of Feeding			
	One Time	Two times	Three times	Four times
% Increase in length	3.57	3.04	2.60	0.31
% Increase in weight	18.47	5.85	28.20	6.22
Survival (%)	57	14	43	43
S.G.R.	2.50	1.04	6.03	1.53
F.C.R.	4.71	7.30	1.50	-
P.E.R.	0.79	0.47	2.19	-
K_1%	21.23	13.71	66.67	-
K_2%	25.09	16.07	89.50	-

SGR - Specific Growth Rate; FCR - Food Conversion Ratio;
PER - Protein Efficiency Ratio; K_1% - Gross Conversion Efficiency
K_2% - Net Conversion Efficiency.

TABLE 20

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF P. INDICUS ADULTS FED AT SIX PERCENT RATION SIZE

Parameters	Frequency of Feeding			
	One Time	Two times	Three times	Four times
% Increase in length	8.76	12.50	4.49	1.61
% Increase in weight	9.13	3.18	2.93	2.31
Survival (%)	100	57	100	86
S.G.R.	1.52	0.56	0.48	0.39
F.C.R.	2.24	10.05	8.16	13.39
P.E.R.	1.51	0.59	0.42	0.25
K_1%	44.64	9.95	12.26	7.47
K_2%	48.11	20.1	14.23	8.45

SGR - Specific Growth Rate; FCR - Food Conversion Ratio;
PER - Protein Efficiency Ratio; K_1% - Gross Conversion Efficiency
K_2% - Net Conversion Efficiency.

TABLE 21

ESTIMATED GROWTH, SURVIVAL, SPECIFIC GROWTH RATE, FOOD CONVERSION RATIO, PROTEIN EFFICIENCY RATIO, GROSS AND NET CONVERSION EFFICIENCIES OF P. INDICUS ADULTS FED AT EIGHT PERCENT RATION SIZE

	Frequency of Feeding			
Parameters	One Time	Two times	Three times	Four times
% Increase in length	4.12	6.33	2.49	0.98
% Increase in weight	10.85	7.68	18.92	17.05
Survival (%)	75	50	100	75
S.G.R.	2.01	8.11	2.95	3.07
F.C.R.	4.90	2.87	2.26	5.24
P.E.R.	0.95	1.17	1.52	0.65
K_1%	20.42	34.84	44.25	19.08
K_2%	29.58	38.68	47.49	20.19

SGR - Specific Growth Rate; FCR - Food Conversion Ratio;
PER - Protein Efficiency Ratio; K_1% - Gross Conversion Efficiency
K_2% - Net Conversion Efficiency.

TABLE 22

ANALYSIS OF VARIANCE FOR SURVIVAL

Source	Degrees of freedom	Sum of squares	Mean square	F value	Remarks
Ration	3	5786.50	1928.83	4.49	Sig. (5%)
Frequency	3	1747.50	582.50	1.36	N.S.
Error	9	3864.00	429.33		
Total	15	11398.00			

TABLE 23

ANALYSIS OF VARIANCE FOR SPECIFIC GROWTH RATE (S.G.R.)

Source	Degrees of freedom	Sum of squares	Mean square	F value	Remarks
Ration	3	285.74	95.25	13.93	Hi Sig (1%)
Frequency	3	13.37	4.46	0.65	N.S.
Error	9	61.55	6.84		
Total	15	360.65			

TABLE 24

ANALYSIS OF VARIANCE FOR FOOD CONVERSION RATIO (F.C.R.)

Source	Degrees of freedom	Sum of squares	Mean square	F value	Remarks
Ration	3	147.37	49.12	5.36	Sig (5%)
Frequency	3	21.91	7.31	0.80	N.S.
Error	9	82.49	9.17		
Total	15	251.77			

TABLE 25

ANALYSIS OF VARIANCE FOR PROTEIN EFFICIENCY RATIO (P.E.R.)

Source	Degrees of freedom	Sum of squares	Mean square	F value	Remarks
Ration	3	2.57	0.86	3.00	Sig. (5%)
Frequency	3	1.44	0.48	1.68	N.S.
Error	9	2.58	0.29		
Total	15	6.59			

Fig. 23. Effect on specific growth rate (S.G.R.) of P. indicus adults with change in

(a) feeding frequency

(b) ration size.

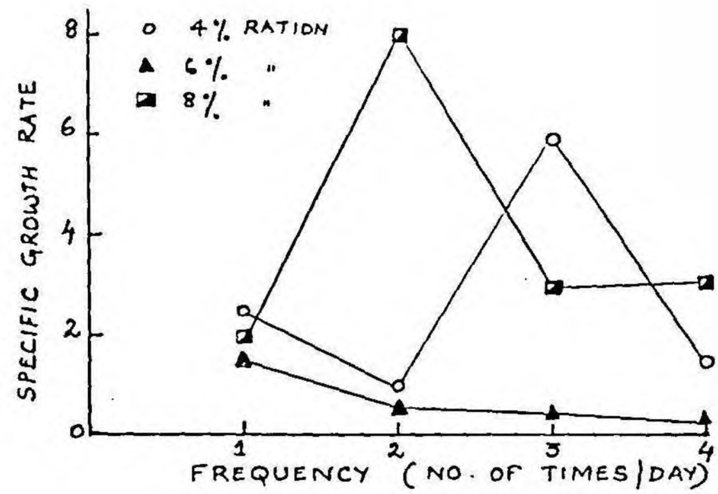


Fig. 23(a)

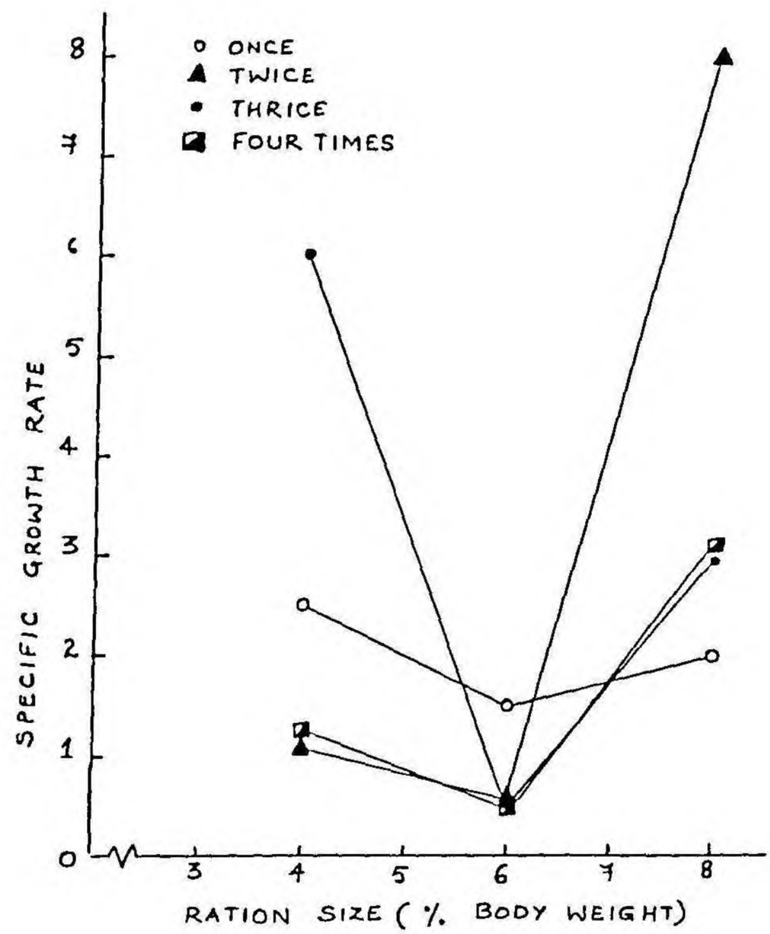


Fig. 23(b)

Fig. 24. Effect on food conversion ratio (F.C.R.) of P. indicus adults with change in

(a) feeding frequency

(b) ration size.

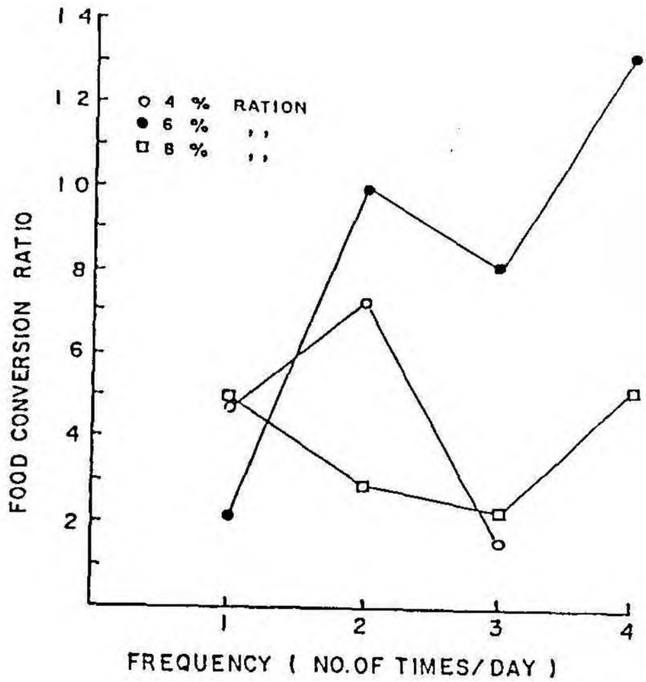


Fig. 24(a)

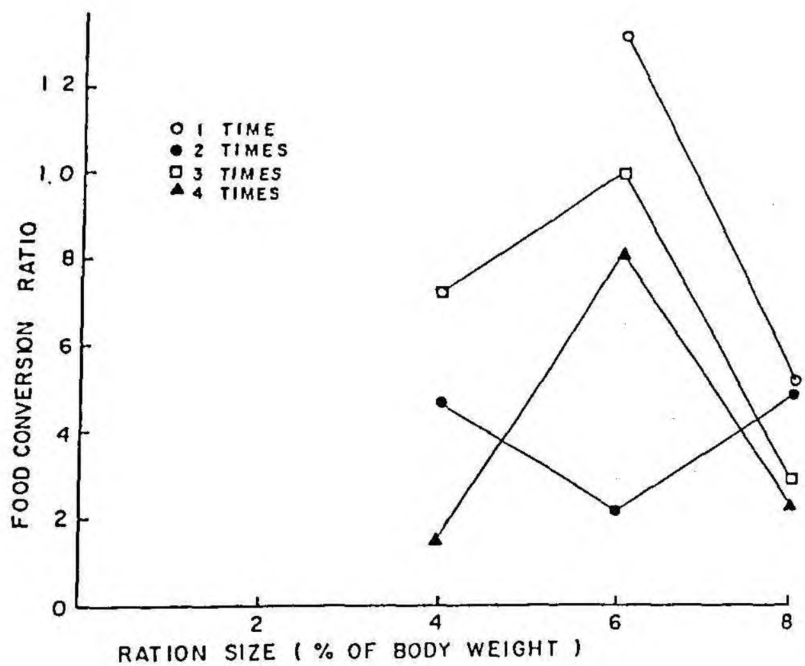


Fig. 24(b)

Fig. 25. Effect on protein efficiency ratio (P.E.R.) of P. indicus adults with change in

(a) feeding frequency

(b) ration size.

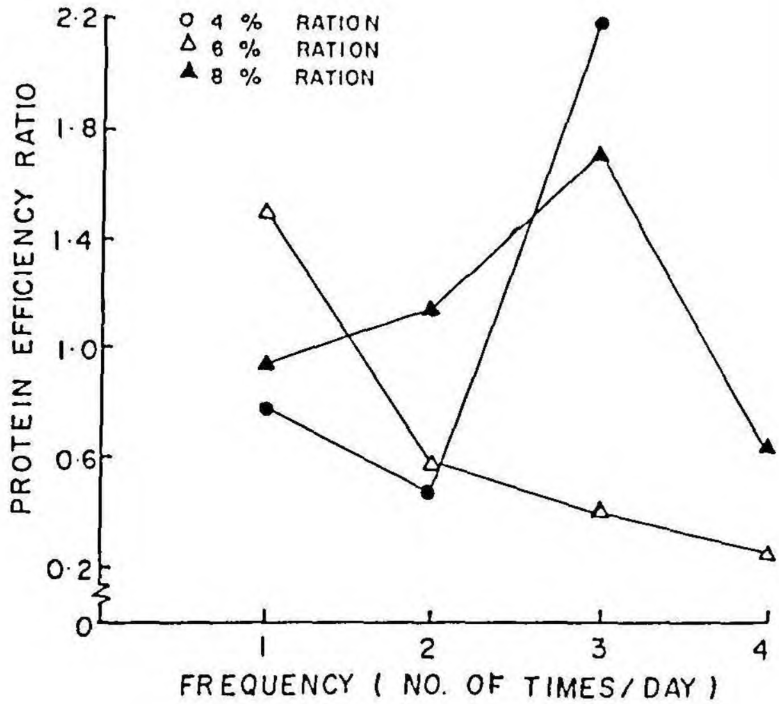


Fig. 25(a)

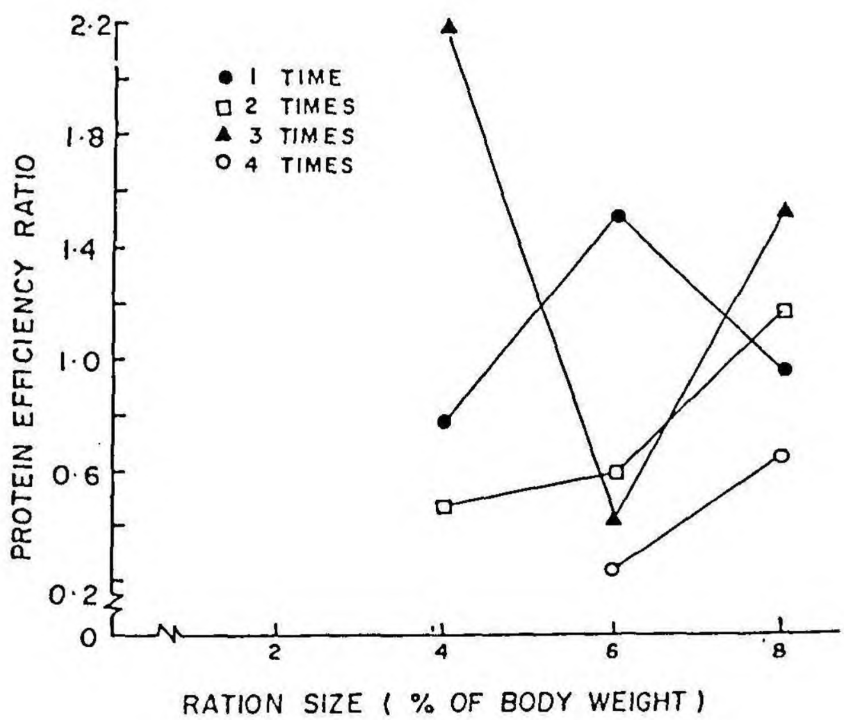


Fig. 25(b)

between ration size and SGR ($P < 0.01$) (Table 23). Frequency of feeding however did not influence the SGR. The best SGR value of 8.1 was observed at the 8% ration size with two times feeding which was closely followed by a value of 6.026 at the 4% ration size with three times feeding (Tables 19 and 21, Fig. 23).

Food conversion Ratio (FCR) and Protein Efficiency Ratio (PER)

FCR and PER values given in Tables 18, 19, 20,21 and graphically in Fig. 24 could not be calculated for the 1% ration size on account of the heavy mortality observed in this group mentioned earlier. Both FCR and PER were observed to be statistically significant ($P < 0.05$) with change in ration size (Tables 24 and 25). The best FCR of 1.5 was obtained at 4% ration size with 3 times feeding followed by values of 2.24 and 2.26 for 6% (one time feeding) and 8% (three times feeding) ration sizes respectively. Similarly the best PER of 2.2 was obtained for adult P. indicus fed 4% ration size thrice a day.

Gross Conversion Efficiency (K_1%) and Net Conversion Efficiency (K_2%)

Growth in terms of K_1 and K_2 was poor in adult P. indicus (Tables 18, 19, 20 and 21). Variations in ration size significantly affected K_1 ($P < 0.05$) (Table 26) but not K_2. K_1 was maximum (67%) at the 4% ration size with three times feeding and least (7%) at 6% ration size with four times feeding. Same was the case observed with K_2.

TABLE 26

ANALYSIS OF VARIANCE FOR GROSS CONVERSION EFFICIENCY (K_1)

Source	Degrees of freedom	Sum of squares	Mean square	F value	Remarks
Ration	3	2056.57	685.52	2.38	Sig. (5%)
Frequency	3	1265.26	421.76	1.46	N.S.
Error	9	2591.13	287.90		
Total	15	5912.97			

Optimum ration size for adults

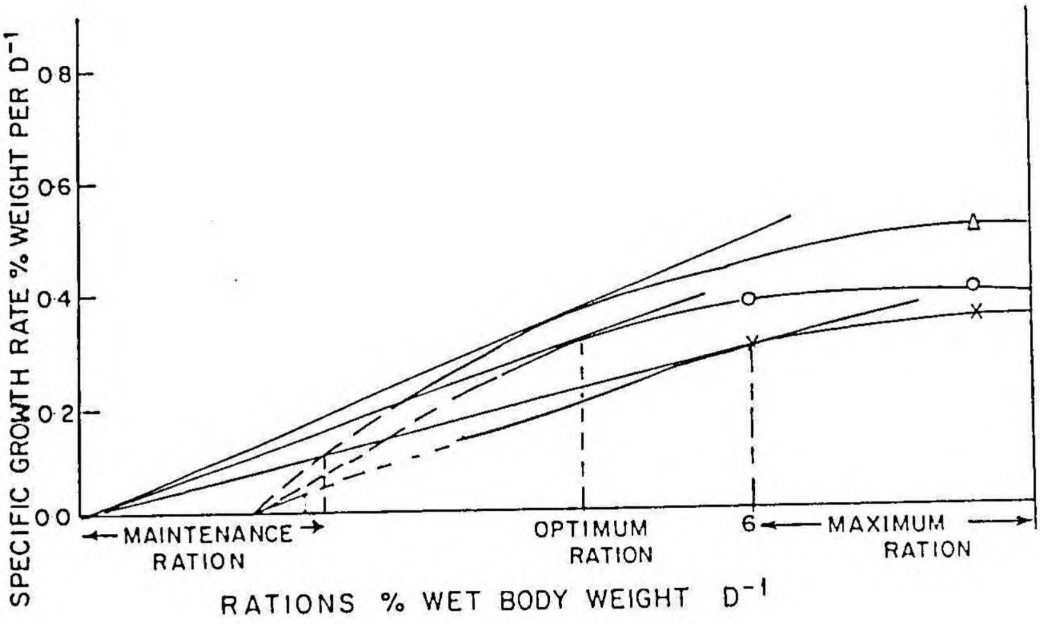
Adult P. indicus fed three times per day gave the highest specific growth rate and maximum conversion efficiency and the optimum ration calculated was at 4.5% of the wet body weight per day. Rations higher than 6% of the body weight were the maximum rations as again there was a decline in the specific growth rates while those below 2% were the maintenance rations.(Fig 26.)

Trypsin activity

Quantitatively, post larvae, juvenile and adult P. indicus displayed trypsin activities. The total and specific activities of trypsin are given in Table 27. Juveniles and adults showed slightly higher enzyme activity than observed for postlarvae. However, no statistically significant correlation could be detected with regard to both ration size and stage of animals ($P > 0.05$).

Postlarvae at the 12% and 22% ration sizes exhibited higher total activities as was also noticed at the 8% and 12% for juveniles and 4% and 6% for the adult animals. The total activity of trypsin in the starved control shrimp was low when compared to the experimental groups. This was not true for the specific activities which were more or less equal in all groups.

Fig. 26. Specific growth, G, of Penaeus indicus adults fed at the varying ration levels and feeding frequency.
(× -fed two times per day; o -fed three times per day; Δ - fed four times per day.



SPECIFIC GROWTH RATE % WEIGHT PER D⁻¹
0·8
0·6
0·4
0·2
0·0
MAINTENANCE RATION
OPTIMUM RATION
6
MAXIMUM RATION
RATIONS % WET BODY WEIGHT D⁻¹

Fig. 26

TABLE 27

STATUS OF TRYPSIN ACTIVITY WITH REGARD TO RATION SIZE IN POSTLARVAE, JUVENILE AND ADULT *P. INDICUS*

Stage of Animal	Ration size (% body weight)	Trypsin Activity[1]	
		Total[2]	Specific[3]
Postlarvae	Starved	3.46	0.068
	2	4.23	0.078
	12	6.69	0.063
	22	6.23	0.072
	32	5.43	0.059
Juveniles	Starved	4.62	0.110
	2	7.24	0.118
	8	8.64	0.110
	12	8.92	0.112
	16	7.72	0.120
Adults	Starved	4.89	0.121
	1	10.23	0.126
	4	11.86	0.109
	6	12.24	0.122
	8	11.43	0.113

1. Activities reported as population mean (n = 8 for post larvae and n = 6 for juveniles and adults respectively.)
2. Total activity reported as μM p-nitroanilide produced . per minute per wet tissue.
3. Specific activity reported as μM p- nitroanilide produced per minute per mg protein.

DISCUSSION

The present study was designed with the purpose of testing the combined effects of varying ration sizes and feeding frequencies on the growth of postlarval, juvenile and adult Penaeus indicus. Although broad generalisations, as applied to large scale maricultural projects cannot be estimated with certainty, the indications obtained from these data do provide clues for future research and field experiments.

The proximate composition analysis of the three commercial feeds viz. starter, grower and finisher used in the present study are very much in agreement with the composition of eight brands of commercial shrimp feed of other manufacturers reported by New (1990) and five brands of imported feeds by Sanhotra and Pereira (1992). The lipid contents of the three feeds used in the present study were found to be slightly higher (7.5% to 8.5%) than the values ranging from 2.8% to 4% usually encountered in other commercial feeds and reported by New (1990). However, our values are more in agreement with those of Sanhotra and Periera (1992) who reported value ranging from 4.95 to 7.85 as the lipid % in the five commercial feeds analysed by them. Generally the feeds were within the standards perscribed for penaeid shrimp and designed to meet the nutritional requirements of postlarval, juvenile and adult P. indicus.

The feeding behaviour of shrimp differs from that of fish making some degree of water stability essential for shrimp feeds. However 24 hour water stability is not only unnecessary if feeding frequency is higher than once per day but may also result in poor palatability in dry feeds (New, 1990; Forster and Gabbot, 1971; Farmanfannaian and Lauterio, 1982; Ahmad Ali, 1988). Feed pellets which disintegrate faster, facilitate faster leaching of nutrients, especially micronutrients, leading to non availability to the animal, pollution of water and economic loss (Forster, 1972). Sanhotra and Pereira (1992) observed a 14-18% loss in the dry matter content of the five commercial feeds analysed by them. The three feeds used in the present study were also found to be highly water stable as after five hours of immersion in sea water only a marginal loss of 16% was obtained in the dry matter content.

The problems of inefficient ingestion in prawns highlights the need to understand precisely the bulk requirements for maximum growth and conversion efficiency, if, economic viability is to be approached in intensive culture. Probably, the most important attribute of penaeid prawns as culture species is their potential for rapid growth. The main objective of this investigation, therefore, was to find a suitable ration size and feeding frequency in terms of growth under the defined conditions in standardised aquaria as manipulation of the feeding regime may result in a reduction in feed costs. (Taechanuruk and Stickney, 1982). Although, ration size had a statistically significant effect ($P < 0.05$) on the growth of postlarvae, juvenile and adult *Penaeus indicus*, frequency of feeding elicited slight, though not statistically significant correlation ($P > 0.05$) with regard to growth in the present study.

RATION SIZE:

The importance of daily ration is clear as excessive feeding is wasteful and possibly deleterious to the water quality while inadequate rations limit growth rate. Research on compounded diets for the postlarvae of P. indicus have hitherto been rare. Forster (1972) reported having fed large (70 mg) postlarvae of P. monodon with a compounded diet and obtained a good survival though slower growth as with fresh food. Khanappa (1977) fed much smaller P. monodon postlarvae (5.5 mg) with a compounded diet based on fish meal and rice bran and found that growth and FCR were best with 30% protein in the diet. Kittaka (1975) also reported satisfactory results in feeding 3 mg postlarvae of P. aztecus with a formulated diet on which P. japonicus had not grown well. The postlarvae of P. californiensis and P. stylirostris have been the subject of feeding experiments with formulated diets (Brand and Colvin, 1977; Colvin and Brand, 1977). Our results yielded overall good survival and F.C.R.'s with the commercial feed at the four ration sizes in postlarvae of P. indicus. However, the best results were obtained in the 12% ration size wherein an F.C.R. of 1.09 was obtained along with the maximum conversion efficiency at a feeding frequency of four times per day.

Jones et al.,(1979) stated mortality as a common problem in feeding processed diets to penaeid larval and postlarval stages. The fact that moulting cycle is much shorter and that reserves are consumed faster in younger stages than in adults emphasises the importance of formulae with the best adapted ingredients and properly balanced calorie rations.

Hysmith et al.,(1972) reported low survival of small P. aztecus postlarvae fed with high protein/low energy and low protein/high energy diets. Hence while growth pattern remained identical, the growth rate varied with feeding rate. However, in our study we did not encounter heavy mortality in any of the treatment groups in the postlarval stages maintained on the commercial feed and survival was better in comparison to that of the clam meat fed control animals. Posten and Williams (1991) showed increase in level of feeding to cause significantly higher percentage protein in fish. Feeding rates higher than 6.43% and 5.46% did not significantly change percentage fat, protein or ash of the fish. The low body fat indicated that fish fed 5.44% and 4.67% body weight per day, or lower were underfed, but feeding levels of 6.43% and 5.46% were sufficient. In prawns there are no studies relating changes in body composition to ration size. However, in our study feeding level had significant effect on proximate body composition of postlarval P. indicus, though differences in body fat paralleled changes in ration size.

Overall results obtained indicate that the optimum feeding rate for postlarvae is 12% which is comparable to the values reported by New (1980) and Paul Raj (1993). The specific growth rate of P. indicus post larvae was also apparently maximum at this ration size.

Environmental conditions yielding 80% to 90% survival in the intensive tank culture of penaeid shrimp encompassed a combination of either no substrate or sand substrate on elevated platforms, air supplied externally by an aeration system and population density of 40 g/m^2 with semipurified pelleted diets (Sick et al., 1972). Caillouet et al., (1976) also reported an increase in average yield of pink shrimp P. duorarum with increase in feeding rate. However in the present investigation, juvenile P. indicus recorded more mortalities and poor survival throughout most of the experimental period, at all the feeding rates on the pelleted feeds giving an overall survival ranging from 16% to 83%. The resulting cannibalism due to moulting and lower densities presumbly allowed the few survivors to grow well. Similar was the case observed in adults though survival was slightly better than that observed in the case of juveniles and ranged from 14% to 100% being statistically significant ($P < 0.05$) with regard to ration size.

In our study, the adult and juvenile shrimp did not consume all the feed right after being fed, at the higher feeding rates, but fed intermittently throughout the full 24 hour day. The results indicated that penaeids were capable of consuming large amount of food. This may be a reflection of their natural tendency to continuously graze upon large quantities of benthic material rather than feed periodically as would a strict carnivore. Both juvenile and adult P. indicus, however recorded better survival rates than the clam meat controls.

Microbial colonisation is believed to be important for detrital feeders such as shrimp and prawns (Caillouet et al., 1973; Newell and Fell, 1975) for it increases the nutritional suitability of the food particles. Feeding once a day allows more time for microbial colonization of feed than feeding two or three times a day as observed by Heinen and Mensi (1991).

Sick et al., (1972) comparing a pelleted feed supplied at 0,5,10 and 15% of total biomass illustrated that growth was directly proportional to an increase in feeding rate in P. setiferus and P. aztecus. Animals fed at 5% of the biomass increased 58% over the initial weight, those fed at 10% of the biomass increased 109% and those fed at 15% of the biomass gained 164%. Taechanuruk and Stickney (1982) studying the effects of feeding rate and feeding frequency on protein digestibility in freshwater shrimp M. rosenbergii reported neither feeding rate nor frequency of feeding to affect digestibility and stated a feeding rate of approximately 2% of body weight daily to be sufficient for M. rosenbergii (adults) greater than 13 grams.

Subramanyam and Oppenheimer (1970) reported greater average length and weight increments of grooved penaeid shrimp, P. aztecus and P. duorarum at 5% than at 10% feed level using pelleted feed. In the present study, the best growth rates were observed at 8% in the case of juveniles and 4.5 in the case of adults.

The success of experimental diets has frequently been assessed in terms of FCR (Forster, 1976; New, 1976) Efficient utilisation can arise however under conditions of restricted food supply when rations are close to the optimum level. The extended time period required to reach market size under these conditions may render the exercise uneconomical, while increased feeding levels may lead to unacceptable inefficiency. Sick et al., (1972) stated that by using semi purified, pelleted diets, food conversion ratios were reduced by nearly half of that reported for penaeids feeding on clam and other natural foods.

Forster (1976) suggested that an arbitrary FCR of 2:1 may be required in tropical prawns before economic viability can be approached. Similar values reported in the literature within this range eg. P. aztecus (Venkataramiah et al., 1974) and for M. rosenbergii (Balaz and Ross, 1976) were probably obtained under restricted rations judging by the growth rates achieved in comparision with those recorded by Forster and Beard (1974). FCR values measured for P. merguiensis close to maximum rations (approximately 1.35:1) obtained with small prawns by Sedgwick (1979) indicates that economic feeding is possible. The best FCR values of 1.09, 1.52 and 1.5 obtained in our study upon feeding juvenile and adult prawns with commercial pelleted feed were also those at the optimum ration and are in close agreement with the results of Sedgwick (1979) and Sick et al.,(1972).

Starved postlarvae, juvenile and adult P. indicus were not able to sustain their initial biomass level beyond 2 weeks. Cannibalism appeared to be prevalent among starved organisms, and the decline in weight was undoubtedly moderated due to growth of animals preying upon dead shrimp an observation also in agreement with Sick et al. ,(1972).

FEEDING FREQUENCY:

A knowledge of the frequency of feeding can be favourably manipulated to avoid overfeeding and reduce wastage (Singh and Srivastava, 1984).

Although not well documented, P. setiferus has been reported to be more active during daylight hours than during night (Anderson, 1966). In contrast, Bishop (1970) reported that P. duororum did not display increased activity or growth with an increase in photoperiod, although Fuss and Ogren (1966) in their studies with P. duororum found that a constant illumination caused an increase in activity. Caillouet et al., (1973) found that feeding penaeid shrimp P. duorarum once or three times per night did not affect survival, growth or yield. In the present study though slight differences were observed with regard to survival, growth and FCR in the one time night and morning feeding it was not significant statistically ($P > 0.05$).

Luquet (1979) found that temperature had a significant effect on feed consumption as well as mean transit time and that a feeding frequency of twice daily resulted in significantly high ingestion and mean transit time in rainbow trout S. gairdineri. Taechanuruk and Stickney (1982) concluded that twice daily feeding was superior to the higher and lower frequencies evaluated and had a significant effect upon ingestion in freshwater shrimp, while Sedgwick (1979) reported that mean weight increases and feed conversion efficiency were improved in P. merguiensis when shrimp were fed four times daily as compared with once a day feeding.

Sreekumaran Nair et al. (1982) studied growth of M. dobsoni and P. indicus and concluded that different levels of feeding did not exert any influence on the two coefficients of the length-weight relation. However, different feeding levels showed definite effects on the growth rate, the maximum growth rate being shown by prawns fed five times a day. In a later study (Sreekumaran Nair et al., 1983) they studied growth of P. indicus under different levels of feeding and reported growth in weight to be exponential under different levels of feeding, while growth in length was nearly linear. A mild increase in these increments with time even in tanks fed twice or thrice a day was observed. Hence they concluded that frequency of feeding rather than abundance of food, independent of its quality, to play an important role in controlling the growth of penaeid prawns.

Comparision of the present results with those of others is difficult because of differences in stocking size, density, habitats, temperature and depths. In the present study no statistically significant correlation ($P > 0.05$) could be deciphered at the different feeding frequencies with regard to survival, growth and proximate body composition in postlarvae, juvenile and adult P. indicus.

Good survival and growth of postlarvae, juvenile and adult P. indicus can be achieved by feeding optimum ration three to four times a day. This feeding regime should be practical for commercial nurseries and hatcheries and can also serve as a standard against which development and performance of a suitable, water stable dry feed can be measured. The rearing system used in our study differs markedly from those used in commercial ventures. Natural food availability in earthen ponds was excluded during the present study. Food availability would evidently be higher in commercial systems. The animals utilised in this study were also isolated in aquaria and there was not much competition for food. The presence of competition in a pond could lead to more rapid and more complete feed consumption than occurred in aquaria, though agonistic behaviour could lead to poorer feed utilisation.

The groups fed more frequently (four times in postlarvae, three times in juveniles and adults) showed best conversion and growth in the present investigation. Increase in the frequency of feeding above three times a day in juvenile and adult P. indicus showed increased feed wastage elucidated in the poor growth and higher feed conversion. Therefore, feeding the optimum rations, four times a day for postlarvae, and three times a day each for juveniles and adults is best suited for maximum growth and better conversion efficiencies in P. indicus.

As the same brand of commercial pelleted feed was fed to the three stages of animals viz. postlarvae, juveniles and adults with not much variation in proximate composition, no diet induced variation in enzyme activity was expected. The little variation observed in the present study in the total activity of trypsin amongst the three size groups shows that variation may be related to the size of the animal and also the amount of protein in the diet as ration sizes varied. This observation is in agreement with that of Lee et al., (1984) who found a differing proteolytic response to protein level and source as a function of size reflecting changes in digestive physiology as the shrimp grow. Moreoever, total enzyme activities reflected differences associated with protein levels but not the specific activities as also observed in the present study. Therefore, the concentration of enzyme in the digestive tract changed in relation to the mass or wet weight of the tract (total activity) but these changes were not so great with regard to the soluble protein of the tract (specific activity).

SUMMARY

1. The three commercial feeds *viz.* starter, grower and finisher used in the present study for feeding postlarvae, juvenile and adult *Penaeus indicus* showed good water stability, with only a marginal loss of 16% in the dry matter content upto five hours.

2. Biochemical analysis of the three feeds reported a moisture content of 7.5% for the grower and 8.35 and 10.3% for finisher and starter respectively.

3. Crude protein content ranged from 29.53% to 36.96% showing the feeds to meet the protein requirements of the three stages of animals.

4. Crude fibre content of starter and finisher feed was 2.3% and 2.8% respectively while that of the grower was slightly higher at 3.2%

5. The NFE content of the three feeds ranged from 53.57 to 51.17% respectively.

6. The grower feed recorded the highest value of 13.59% while the finisher and starter recorded values of 11.16% and 12.62% as the ash content.

7. Based upon the protein, fat and carbohydrate contents, the starter, grower and finisher feeds recorded values of 20.85, 20.48, 20.47 KJg^{-1} respectively as their calorific values.

8. The three feeds showed chitin values of 1.58, 1.32 and 1.28% for starter, grower and finisher feeds respectively.

9. The calcium contents recorded in the starter, grower, and finisher feed were 2.95, 2.25 and 2.15% respectively while available phosphorus values were 0.71 0.64 and 0.55% respectively. The starter feed recorded a value of 0.62% and the grower and finisher 0.52% each as the sodium content.

10. Survival of postlarvae was found to be statistically significant ($P < 0.05$) with regard to charge in ration size and 100% survival was obtained at 12% ration size. Feeding frequency however did not reflect any statistically significant variations ($P > 0.05$).

11. Variations in ration size and feeding frequency failed to reflect any significcant difference ($P > 0.05$) in the performance of postlarvae in terms of FCR, PER, K_1 and K_2 though significant difference was observed in terms of SGR ($P < 0.01$) with regard to ration size.

12. Optimum ration size of postlarvae of P. indicus as calculated by plotting the various ration sizes (in % body weight per day) against specific growth rate (in %) weight per day was 12%. Rations below this were termed maintenance rations while values above this were termed maximum rations.

13. The best FCR of 1.09 and maximum K_1 value of 91.74, K_2 value of 147%were also obtained at the 12% ration size with four times feeding.

14. High mortality at all the ration sizes was encountered in juvenile P. indicus so that survival ranged from 16% to 83%.

15. Variations in ration size and feeding frequency failed to reflect any significant differences ($P > 0.05$) in the performance of juveniles in terms of S.G.R , P.E.R, K_1 and K_2.

16. FCR was highly significant ($P < 0.01$) with regard to ration size in juvenile P. indicus with the best F.C.R. of 1.52 and maximum K_1 and K_2 values being obtained at the 8% ration level with three times feeding.

17. Optimum ration size for juvenile P. indicus was 8% body weight per day.

18. Survival in adult P. indicus ranged from 25% to 100% and was significant ($P < 0.05$) with regard to ration size.

19. Significant difference was observed in S.G.R. ($P < 0.001$), F.C.R. and K_1 ($P < 0.05$) in adult P. indicus with regard to ration size.PER and K_2 failed to elicit any statistically significant difference ($P > 0.05$) with regard to variation in ration size and feeding frequency.

20. Optimum ration size obtained for adult P. indicus was at 4.50% body weight per day.

21. Best FCR of 1.5 and maximum conversion efficiency was obtained at 4.50% ration size with three times feeding.

22. Ration size and feeding frequency failed to elicit any statistically significant variations ($P > 0.05$) with regard to protein, lipid, ash and moisture content of the experimental animals.

23. Total trypsin activity reported as μM p - nitroanilide produced/ minute/g tissue was slightly lower (4.23-6.69 μM) in postlarvae in comparison to juvenile (7.24-8.92 μM) and adult (10.23-12.24 μM) P. indicus respectively with regard to variation in ration size.

24. Starved postlarvae, juvenile and adult P. indicus reported lower enzyme activity.

25. Specific activity reported as μM p - nitroanilide produced/minute/per mg protein however exhibited no significant variation with regard to ration size and starvation.

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